MANUAL
of
GURLEY
HYDRAULIC ENGINEERING INSTRUMENTS

GRAND PRIZE Certificate and GOLD MEDAL awarded W. & L. E. Gurley for Hydraulic Engineering Instruments at the Panama - Pacific International Exposition, San Francisco, 1915.

Manual

of

Gurley Hydraulic Engineering Instruments

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W. & L. E. GURLEY, *Makers*

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FOREWORD

The importance of an exact knowledge concerning the surface water supply of the country has been recognized for many years. The immediate necessity for stream flow data, to be used by those interested in or engaged upon problems of hydraulic engineering, including water power, domestic water supply, sewage disposal, inland navigation, irrigation, swamp and overflow land damage and flood prevention, has created a constantly increasing demand for accurate stream flow measurements.

The relative importance of the different uses of the surface water supply of the country varies, not only in different localities, but also from time to time in the same section as industrial conditions change. These uses all require accurate quantitative estimates for their successful application.

Without question the relation of stream flow records to the economic development of the country is one of continually increasing interest. The desirability of investigating its water resources, one of the most valuable natural assets that a country possesses, cannot be too strongly emphasized.

Considering these facts and also the many costly experiences resulting from misinformation, it is apparent that all data must be collected with appropriate equipment, including properly designed and well constructed instruments, in order to be accurate and dependable. Inasmuch as it is usually impossible to predict future uses of stream flow data at the time the records are made,—in many cases most urgent demands for dependable long time records are made when it is impossible to produce them,—all stream gaging work should progress toward the collection of continuous records of the highest standard of accuracy. The energies of some of the foremost engineers of the world have been given to this work, and as a result both methods and appliances have been highly perfected.

FOREWORD

For many years W. & L. E. Gurley have been the leaders in the manufacture of instruments for the measurement of water. At the Panama-Pacific International Exposition they were given the highest award for Hydraulic Engineering Instruments.

Every part of these instruments is constructed from carefully selected material, and is accurately made and finely finished by experienced workmen in the Gurley Factory, which has been producing precision instruments and equipment for over seventy years. They consist of *Engineering and Surveying Instruments*, such as Transits, Levels, Compasses, Plane Tables, Alidades, Sketching Cases, Leveling Rods and Stadia Rods; and *Standard Precision Weights and Measures*.

The methods commonly used in carrying on water measurements are described in standard text books, to which frequent reference has been made in preparing this Manual. We are indebted to prominent hydraulic engineers for suggestions and photographs, and grateful acknowledgment is hereby made to these friends for their co-operation, as well as to the authors quoted in this book.

W. & L. E. Gurley

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PART I.

GURLEY CURRENT METERS

(PRICE PATENTS)

THEIR CONSTRUCTION, CARE AND USE*

INTRODUCTION

For more than thirty years W. & L. E. Gurley have made Current Meters under the patents of W. G. Price, the Assistant Engineer of the Corps of Engineers, United States Army, who in 1885 devised the initial pattern. The general features are retained in the latest models, although somewhat modified as the result of suggestions from many hydraulic engineers who have had large experience in current meter observation under all conditions of service.

The many hundreds of Gurley Current Meters in use in all parts of the world, their constantly increasing sale and their accuracy and reliability under all conditions, show that they are the standard instruments for the accurate measurement of the velocity of water in streams and open conduits.

A current meter for measuring the velocity of flowing water comprises two essential parts: (a) a wheel arranged so that when suspended in flowing water the pressure of the water against it causes it to revolve; (b) a device for recording or indicating the number of revolutions of this wheel. The relation between the velocity of the moving water and the revolutions of the wheel is determined by rating each meter.

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* Largely quoted from "The use and care of the current meter, as practised by the U. S. Geological Survey," by John C. Hoyt, Trans. Am. Soc. C. E., volume 66, page 70, 1910.

"River Discharge," by Hoyt & Grover, for sale by W. & L. E. Gurley, price $2.00 postpaid, gives a complete treatise of the methods of collecting and analyzing stream-flow data. In the preparation of this Manual this book has been largely used and many direct quotations are made from it.

The essentials of a good current meter are (a) simplicity in construction, with no delicate parts which easily get out of order; (b) a small area of resistance to the velocity of the water; (c) a simple and effective device for indicating the number of revolutions of the wheel; and (d) easy adaptability to use under all conditions.

DESCRIPTION OF THE GURLEY CURRENT METER AND EQUIPMENT

The small Gurley Current Meter and equipment consists of five pincipal parts: (1) the head; (2) the tail; (3) the hanger and weights; (4) the recording or indicating device; and (5) the suspending device. In the following descriptions the numbers in parentheses refer to Fig. 1.

1. THE HEAD. The head consists of a ⊃-shaped yoke (1) carrying a wheel made of six conical cups (2), attached to a horizontal frame (3). This wheel, referred to as the cups, turns in a counter clockwise direction on a vertical axis known as the cup shaft, which rests and revolves on a pivot point bearing at the lower end and engages the recording mechanism at the upper end.

The Cup Shaft consists of two parts (4, 5) clamping the cup frame. They are screwed together from either side of the frame, thus fastening the cups rigidly and at right angles to the cup shaft. At the lower part of the cup shaft there is a bucket nut having a pivot bearing which receives the pivot point (6) on which the cups revolve.

The Pivot Point is screwed through a metal bushing (7) known as the frame nut, and is firmly held by a lock-nut (8). The frame nut slides into the lower arm of the yoke, and is clamped in position by a set-screw. By means of a raising nut (9) on the lower part of the shaft, the cups should always be lifted from the pivot point when the meter is not in use. This raising nut has a left-hand thread, so that it will not tighten when the cups revolve when in use.

The upper part of the cup shaft is fitted with either a worm gear or an eccentric that passes into a cylindrical cham-

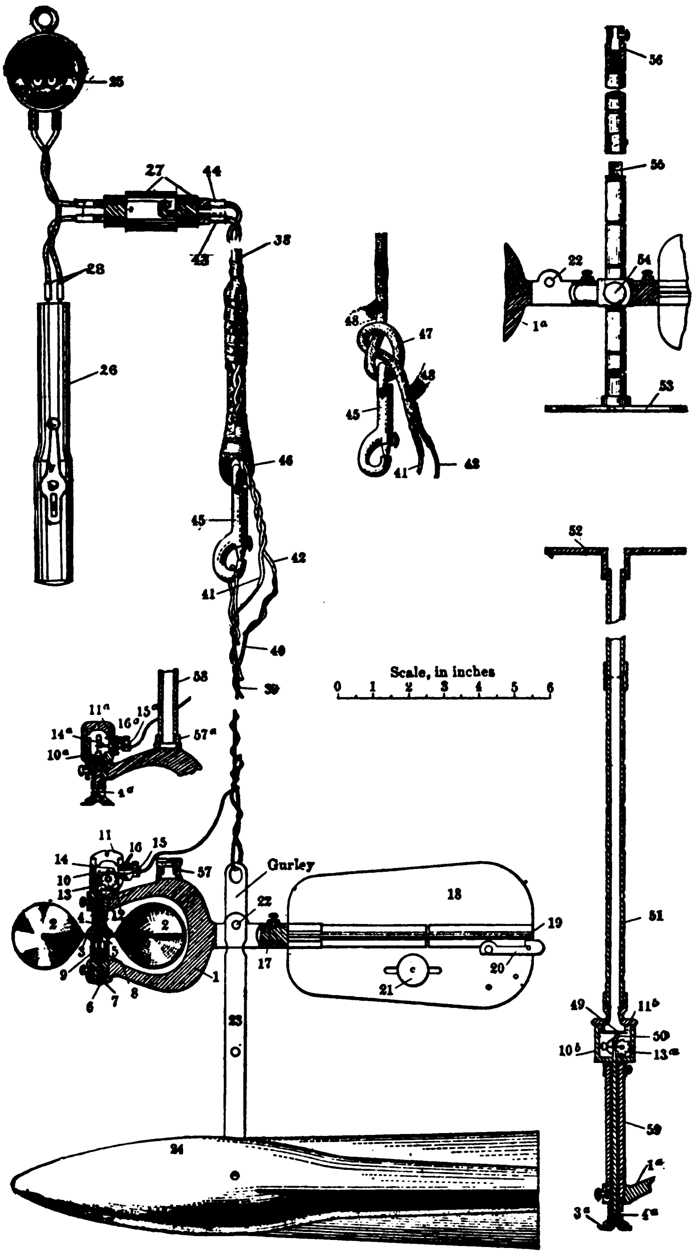


Fig. 1.— Gurley Current Meter and Attachments.

ber (10), known as the *contact chamber*. This chamber contains the mechanism for making the contact which indicates the revolutions of the cups. The construction and arrangement of both the contact chamber and the mechanism contained in it depend on whether the indicating device is penta-count electric, single-count electric, or acoustic.

When the *penta-count electric indicating device* is used, the contact chamber (10) which is closed by a screw cap (11), provided with a leather gasket for keeping out the water, is held by a sliding fit in the upper end of the yoke, and is clamped in position by a set-screw. In the contact chamber there is fitted a cylindrical plug (12) which is held in position by a screw and carries a gear-wheel (13). This engages the worm gear on the upper end of the cup shaft, the gearing being so arranged that the wheel makes one revolution for every twenty revolutions of the cups. On the side of the wheel are four pins, equally spaced and set so that they will strike the contact spring (14) at each fifth revolution of the cups, thus closing the electric circuit to the indicating device, explained later. These contact parts are known as the contact wheel, the contact pins, and the contact spring. The contact spring is carried by the contact plug (15) which is screwed into the contact chamber through a hard-rubber bushing (16) that insulates the contact spring from all other parts of the meter when it is not touching one of the pins on the contact wheel. In the outer end of the contact plug there is a hole and a set-screw for connecting one wire from the indicating device.

When the *single-count electric indicating device* is used, the contact chamber (10a) and appurtenances are the same as described for the penta-count contact chamber, with the exception that the gear wheel (13) is omitted and the worm gear on the upper part of the shaft (4) is replaced by the eccentric (4a) that strikes the contact spring (14a) at each revolution, thus closing the electric circuit to the indicating device. The penta- and single-count contact chambers are interchangeable.

The electric indicating device is used when the meter is suspended from a meter cord attached to the stem (23), or is held by a rod either screwed into the coupling (57), or sliding through the connection (54).

When the *acoustic indicating device* is used, the contact chamber (10b) is closed with a cap (11b) fitted with a metal drum (49), and, in place of the contact spring (14) and plug (16), there is a small hammer (50) which is caused by the pins on the side of the gear-wheel (13a) to strike the drum at each tenth revolution of the cups. In order to keep the water from deadening the sound by rising into the contact chamber (10b), it is raised about four inches above the yoke (1a) by inserting the tube (59) and lengthening the upper part of the shaft (4a). The acoustic meter is always supported on a rod (51) attached to the contact chamber.

2. THE TAIL. The tail is used when the meter is suspended by a cable, or on a sliding hanger rod. It balances the head, and also keeps the axis of the meter parallel to the direction of the current. It consists of a stem (17) which is held by a sliding fit into a socket in the stem of the yoke, in which it is clamped by a set-screw. On this stem there are two vanes (18 and 19) set at right angles. One of the vanes is rigidly attached to the stem; the other fits into grooves on the first and may be pulled out readily when the key (20) that holds it in place is turned. On one of the vanes there is a slot carrying a weight (21) that can be adjusted to balance the meter.

3. THE HANGER AND WEIGHTS. When suspended by a cable, the meter is hung by a screw-bolt (22) on a steel stem (23) that passes through a slot in the stem of the yoke. The slot in the stem of the yoke is wide enough to allow the meter to swing freely in a vertical plane, and the bolt passes through the frame a little above the center of gravity of the meter, so that the latter will readily adjust itself to a horizontal position. In the upper end of the hanger there is a hole for attaching the suspended cable, and at intervals along the stem there are other holes by which the meter and lead weights may be hung. The weights (24) are of torpedo shape,—a design which offers the least resistance to the current,—and are made in three sizes weighing, respectively, 6½, 10 and 15 pounds. They are attached to the stem by a screw bolt. The order in which the weights and meter are placed on the stem, depends on the conditions under which the measurements are to be made.

When the meter is used on a rod, the hanger, the weights, and sometimes the tail are dispensed with.

The set-screws for clamping the various sliding fits are all of the same size and are of standard make. Beveled grooves are provided in each of these connections, so that when the set-screws engage them the parts are drawn into place.

All parts of the meter are standard, and can readily be replaced in the field. Parts should always be ordered by Shop Number from the illustrations in the Price List.

4. The Recording or Indicating Device. A recording or indicating device is necessary for determining the number of revolutions of the meter wheel, and the successful use of the meter depends largely on this part of the apparatus. Various devices, operated either on the mechanical, electric, or acoustic principle, have been used for this purpose. These include the telegraph ticker, automatic recorder, electric buzzer, telephone receiver, drums, etc. Of these, however, the telephone receiver and the acoustic indicator have been found to be most satisfactory in general practice.

The *telephone attachment* consists of a telephone receiver (25) and small battery (26) placed in a partial circuit which terminates in a connecting plug (27) by means of which the apparatus can be readily connected in circuit with the meter. The magnets of the telephone receiver are wound so as to secure a loud click.

The dry battery (26) is compact and can be renewed readily. It is enclosed in a nickel-plated case similar in shape to that of a fountain pen. This case is equipped with a connecting plug to receive the two wires.

In use, the telephone receiver is fastened on the shoulder by a large safety pin, or is held at the ear by an operator's head band, which is worn under the cap, if preferred. The battery cell is placed in the coat or trousers pocket. The connecting plug (27) should hang below the shoulders and be easily accessible for attaching and detaching the meter circuit.

In the *acoustic indicator*, the striking of the hammer (50) on the drum (49) in the contact chamber (10b) indicates each tenth revolution of the meter, as already explained. The sound is transmitted through the rods (51) and a rubber tube

to the ear of the operator. The rubber end and ear-piece are not necessary unless there is considerable noise.

Audible indicators, such as the telephone and the acoustic signalling device, have the advantage of enabling the operator to detect any irregularities caused by trouble with the meter, battery, electric circuit, or any part of the equipment. A stop-watch is necessary for the proper observation of time.

Electric recording devices are sometimes used, particularly when measuring the discharge of large navigable streams. For this purpose specially designed boats manned by several assistants are used.

5. THE SUSPENDING DEVICE. The suspending device, which consists of a rod or of some form of cable, must provide for lowering the meter and weight into the water and also for completing an electric circuit which includes the contact chamber, the meter, and the recording device.

The rod in common use in connection with the electric recorder consists of a ½ inch tube (55) graduated to feet and tenths. For convenience in carrying, it is made in 1.0, 1.5 or 2 foot sections fitted with screw threads, the 2 foot section being standard. The sections of the rod are connected by flush joints which offer no obstruction to the movement of the sliding hanger.

Two methods of hanging the meter on the rod are in use. By the first the head and tail of the meter are attached to a sliding hanger (54), which can be moved up and down the rod or clamped in any position. On the bottom of the rod there is a flat base (53) which keeps it from sinking into the bed of the stream, and at the top there is a plug (56) for connecting one of the wires from the recording device. The circuit between the meter cups and the recording device is made by attaching one of the wires from the recording device to the plug in the top of the rod. The other wire follows down the rod and is attached to the contact plug of the meter. In the second method the rod (58) is connected by the screw socket (57) in the yoke.

The rods (51) for use with either type of meter are of ½ inch tubing graduated to feet and tenths and, for convenience in carrying, are made in 1.0, 1.5, or 2 foot sections which screw

together. The bottom rod connects with the contact chamber (49) by a screw, and is cut so that the zero reading is the plane of the center of the cups. On the upper end of the top rod there is a flat plate (52) in the center of which there is a hole through which the sound from the drum can be heard. The soundings are made with this end of the rod, and the plate keeps the end from sinking into the bed of the stream.

The meter cables must be strong enough to support the weight required to hold the meter in place while making observations, must be water-proof to avoid short circuits and must be tough and flexible to withstand hard usage. They should be as small in diameter, consistent with strength, as is possible, in order to offer small resistance to the water. They may be graduated in feet by means of markers, for convenience in measuring depths. Greater precision in such measurements is obtained by using a single index point and applying it to a fixed scale. This method eliminates the effect of any possible stretch in the cable. When used on a cable reel, (See Fig. 2) the scale and index are part of the reel.

Reels should be used at any place where a considerable number of measurements are to be made, both as a matter of convenience in handling the equipment and to protect the elec-

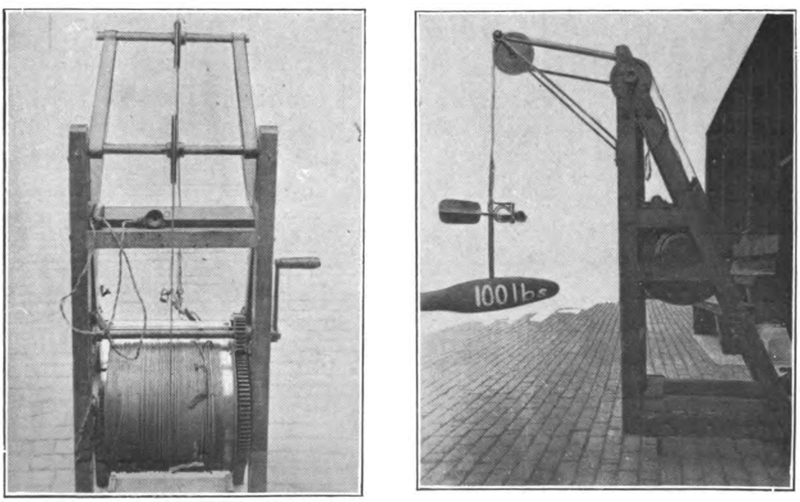


FIG. 2.— Reel for use with Gurley Current Meter. Designed for use on a railroad bridge having a narrow foot walk. The reel is fastened on the side opposite the meter, so as to prevent it from tipping.

tric circuits in the meter cable from the effects of twisting and abrasion.

SELECTING THE PROPER TYPE OF CURRENT METER

Gurley meters are made in several different patterns, thus allowing a wide range for selection.

The selection should be made after consideration has been given to the following factors:

(1) The purpose for which the instrument is to be used.
(2) The manner in which it is supported.
(3) The amount of weight to be used.
(4) The frequency of the revolutions to be indicated.

When it is possible for the observer to approach the stream closely, and to hold the meter in position by means of its suspension rod, especially in channels of small depth, the Accoustic Current Meter No. 616 is very useful. This meter indicates every tenth revolution.

No. 616, the Acoustic Current Meter, is so called because the revolutions of the bucket wheel are indicated by the sound

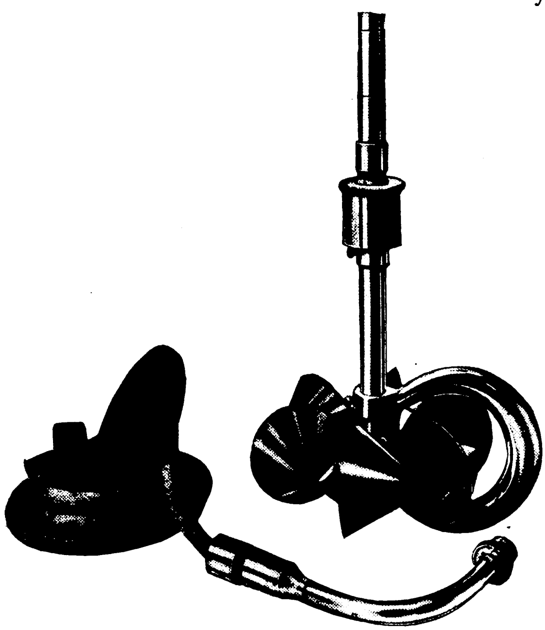


Fig. 3.— No. 616 Acoustic Current Meter, with jointed wading rod, rubber tube and ear piece.
Indicating every tenth revolution.

of a hammer striking against a diaphragm, one blow for every 10 revolutions. The indicating mechanism is completely enclosed and thoroughly protected from injury. When in use the meter is held by a jointed hollow rod, which screws into the frame and in connection with a rubber tube and ear piece attached to it, forms a passage through which the sound of the hammer stroke is transmitted to the ear of the observer. This enables him to count the number of revolutions of the wheel in any given space of time, and then by means of the reduction table to ascertain the velocity of flow.

Many observers prefer an electric type of revolution indicator. In some cases it is desirable to have more than one person hear and bear witness to the number of revolutions. For this purpose an electric indicator is preferable. To meet these demands No. 618 is offered. This style of meter is adapted to channels of small depth and has a metal base on the yoke which prevents the meter sinking into the bed of the stream.

Suspension is made by a graduated tube which is screwed into the frame, permitting the meter to be held by the observer.

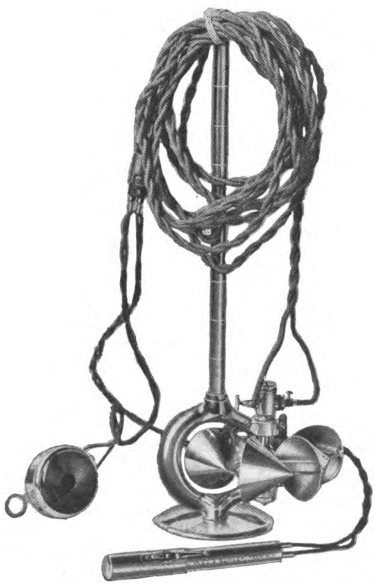


FIG. 4.— No. 618 Electric Current Meter, with base; also telephone sounder, cable and dry cell battery.
Indicating each revolution.

This meter indicates each single revolution of the bucket wheel electrically by a telephone sounder.

All other Gurley meters of the electric indicating type may be equipped for use on rods. (See Meters Nos. 623 and 624, pages 24 and 25.)

For work that requires the meter to be suspended by means of a meter cord or cable, two types are offered. Of these the

FIG. 5.— No. 617 Electric Current Meter, with telephone sounder, cable, dry cell battery, and lead weight. *Indicating each revolution.*

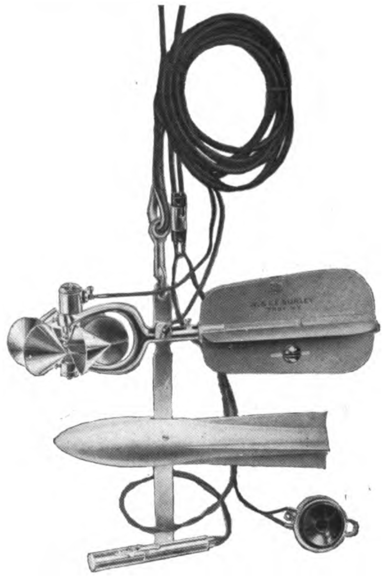


FIG. 6.— No. 621 Electric Current Meter, with telephone sounder, cable, dry cell battery, and lead weight. *Indicating each fifth revolution.*

contact chamber of No. 617 is arranged to indicate each single revolution of the cups, while the contact chamber of No. 621 indicates each fifth revolution of the cups.

These meters are suspended in use by a wire or cable attached to the steel weight hanger which, after passing through the frame, suspends the torpedo-shaped weight necessary to hold the meter in the vertical plane against the current.

A tail, consisting of a stem to which are fastened two vanes (separable in packing), is attached to the frame opposite the bucket wheel and serves the double purpose of balancing the bucket wheel and keeping the meter parallel to the direction of the current.

All of the advantages of the preceding types are combined in Meter No. 623, which is adapted for more universal service than any of the other patterns, as it can be used for measuring both low and high velocities, and can be suspended by means of a cable or by a jointed wading rod.

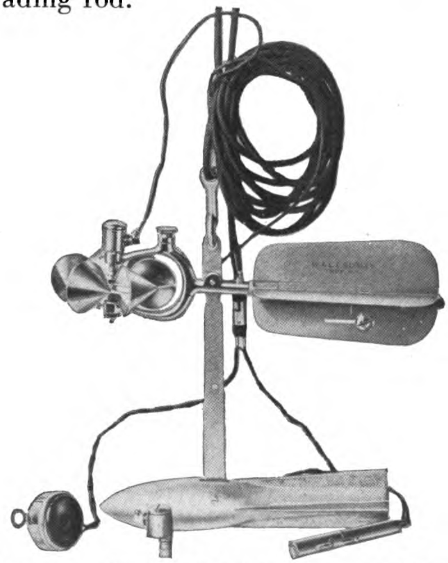


Fig. [illegible].— No. 623 Electric Current Meter, suspended by cable; with telephone sounder, dry cell battery, lead weight and extra commutator box.

Indicating each, or each fifth, revolution.

Fig. 8.— No. 623 Electric Current Meter, suspended by a jointed wading rod, with telephone sounder, cable, dry cell battery, and extra commutator box.

Indicating each, or each fifth, revolution.

The combination of these features provides an outfit which has been adopted as standard by the most efficient hydraulic engineers. This meter is used extensively by the Water Resources Branch of the United States Geological Survey, the

leading organization devoted to the precise measurement of water.

Two contact chambers, one to indicate each revolution, the other each fifth revolution of the bucket wheel, are provided. These contact chambers may readily be interchanged, the only change being in the shaft and consisting of the insertion on the end of the bucket shaft of a cam when a single revolution is to be indicated, or of a worm when it is desired to indicate every fifth revolution.

A screw socket is provided on the frame of the meter to receive a series of graduated rods by which the meter may be suspended, if desired, instead of by a cable, no change being made in the meter except the removal of the weight stem. This modification, the idea of Mr. C. C. Covert, of the United States Geological Survey, is named after its designer, the Covert Yoke. Meter No. 623 thus combines Meters Nos. 617, 618 and 621.

If the Covert Yoke is not wanted, Meter No. 623 can be furnished with a yoke or frame as supplied with No. 617 and No. 621, and with this modification the meter is listed as No. 624.

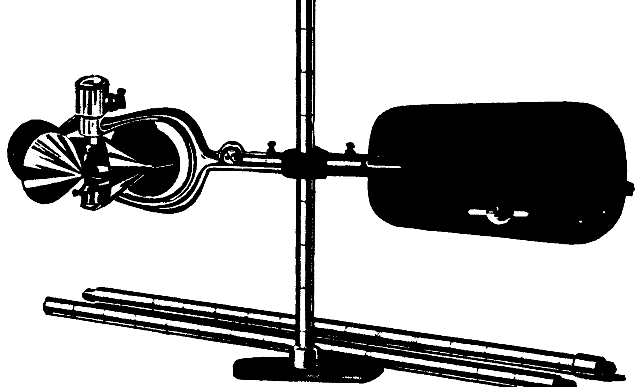


Fig. 9.— Nos. 617, 621 or 624 Current Meter, attached to a flush jointed wading rod by a double end hanger.

By means of a double end hanger, Meters No. 617, 621 and 624 can be used with a flush jointed wading rod. The hanger holds the frame and bucket wheel on one side, and the vane of the meter on the other side of the rod, as shown in Fig. 9.

The largest size Gurley meter, No. 600, is of heavier and more substantial construction than the smaller patterns, as it is built for use in certain investigations of large rivers and harbors where the force of the current is great and the consequent requirement is for an instrument which will withstand extraordinarily hard usage.

FIG. 11.— No. 609 Electric Register.

Electric Register No. 609 in enclosed in a brass case, showing three dials under a glass face. The larger one records each revolution up to one hundred, the smaller one on the right records each hundred revolutions, and the one on the left records each thousand revolutions, all reading clockwise as indicated by the figuring.

It can be placed anywhere in the circuit and each revolution of the meter makes a contact that actuates an electro-magnet that causes a pawl to carry forward a ratchet wheel one tooth at every contact.

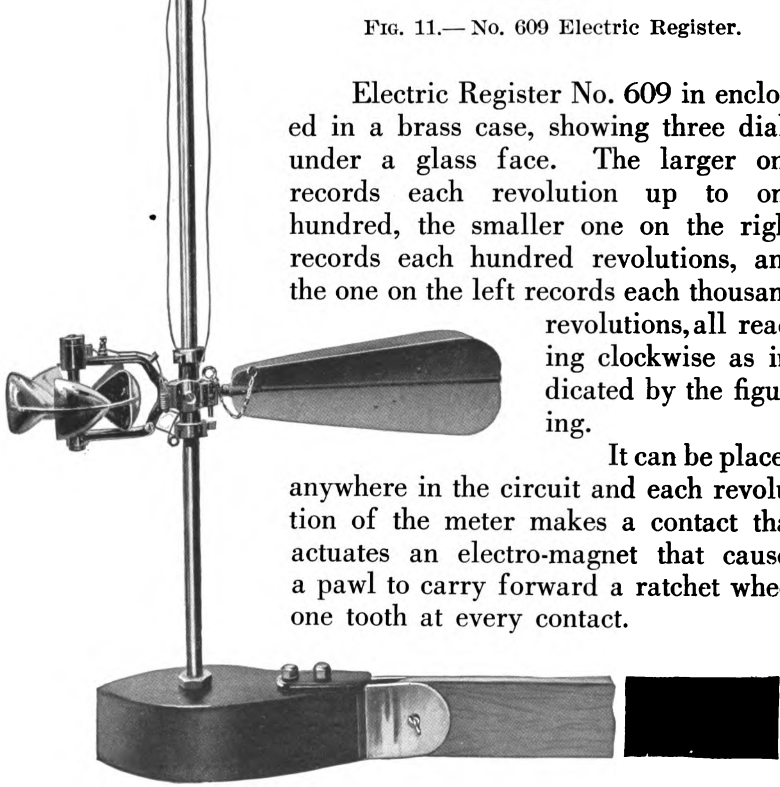


FIG. 10.— No. 600 Electric Current Meter, large size, for harbors and rivers, with No. 606 Lead Weight and Connections.
Indicating or recording each revolution.

All current meters are packed in a wooden box with lock, hooks and carrying strap, and including accessories of oil can, wrench, screwdriver and extra pivot bearing.

A special carrying case of fibre, having two compartments, one for the meter and the other for the lead weight, cable, sounder, etc., as shown in Fig. 12, can be furnished at an additional price, for Meters No. 617, 621, 623 or 624.

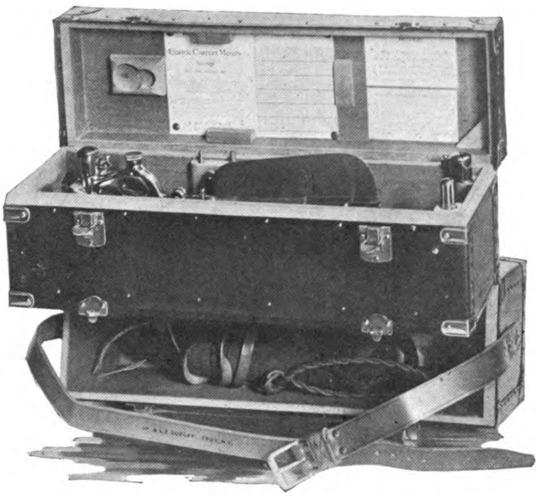


FIG. 12.— Special Fibre Carrying Case for Current Meters.

Meters are ordinarily supported on either graduated rods or on meter cables. Standard graduated rods are best adapted to low velocities and to depths not exceeding five feet. For high velocities or greater depths it is necessary to use rods of special design.

The cable must be strong enough to properly support the amount of weight used, to hold the meter in place. It must also be water-proof and of high quality. The cable usually consists of No. 16 old code double insulated show window cord, which will properly support the weights generally used. For those exceptional cases where heavy weight is required, an appropriate increase should be made in the size of the cable.

The amount of weight to be used depends on the velocity of the current to be measured. A single fifteen pound weight

will serve for the measurement of ordinary velocities. Thirty pounds weight is sufficient for all cases of ordinary practice. A single thirty pound weight is preferable, but for convenience in handling two fifteen pound weights may be used. When more weight is used it should be in one piece and when placed on the hanger the top of the weight should be not less than six inches from the bottom of the cups.

The frequency with which the revolution of the cups will be indicated depends on the velocity of the water to be measured. For velocities under four feet per second the contact indicating each single revolution should be selected, but for higher velocities the contact indicating every fifth revolution should be used. Electric Register No. 609 will record satisfactorily all usual velocities with either style of contact chamber.

ADVANTAGES OF GURLEY CURRENT METERS

Reliability in service. These instruments have been developed to meet the exacting requirements of field service. The details of construction have been improved from time to time to insure continuous reliability under actual working conditions. They may be depended upon to give accurate results under trying conditions.

Simplicity of design. The details of design are extremely simple. The instrument is self-contained. There are no delicate adjustments required, nor are there any exposed parts to give trouble.

Rigidity of construction. Gurley meters are strongly constructed. They will resist successfully all of the stresses and shocks incident to travel and field service.

Adaptability. Gurley meters are equally well adapted to the measurement of small streams and large rivers. A single meter may be used on both classes of work by simply altering the method of suspension.

Size. The compactness of the Gurley meter is a material advantage. It can be packed when traveling in a box small enough to be carried in a hand bag. Its size is also an advantage in handling when in actual use.

COMPLETE CURRENT METER FIELD OUTFIT

A complete current meter outfit for field use consists of:

(1) Meter itself, with its rating table.
(2) Telephone or other indicating device, connected up with insulated wire in circuit with dry cell and connecting plugs, ready for use.
(3) Oil can, filled with clock oil.
(4) Small screw driver.
(5) Spanner wrench for dismantling the meter.
(6) Cable for supporting the meter, equipped with snap.
(7) Torpedo weights.
(8) Hanger.
(9) Hanger screw.
(10) Stopwatch.
(11) Rods for wading measurements.
(12) Notebook, containing blueprint of rating table for the meter used, a list of special tools, equipment, and also clothing, to be carried if the trip is to be an extended one.

The Notebook should also contain a supply of note forms, including

Discharge Measurement General Data, Form No. H-325 (See page 54).
Current Meter Notes, Form No. H-326 (See page 55).
Current Meter Notes—Ice Cover, Form No. H-327 (See page 60).
Inspection of Recording Register Stations (See page 127).
Level Notes.
Sketch Sheets.

It will be convenient to be supplied with the following articles, which are frequently necessary or desirable for making repairs to the station equipment and for the ordinary operation of the current meter:

(1) Parallel pliers with wire cutter.
(2) Bottle of special clock oil, which will not clog in cold weather.
(3) Roll of adhesive tape.
(4) 25-foot metallic tape.

(5) 50-foot steel tape.
(6) Extra pivot point.
(7) Extra set of screws, for meter.
(8) Extra screws, for hanger.
(9) Extra battery, with binding posts wound with insulating tape.
(10) Extra contact spring in rubber bushing.
(11) Insulating wire.
(12) Small hatchet.
(13) Assortment of nails. Piece of twine. Piece of cotton cloth, for drying meter.

CARE OF THE CURRENT METER

TO TAKE THE METER APART

When taking the meter apart, remove the tail vanes and the hanger stem; then loosen the set-screw to the contact chamber, and pull the chamber out by a slight twisting motion. Care must be taken to let the cups be free to turn, so that the worm gear on the upper end of the shaft can disengage from the teeth of the contact wheel. In handling the contact chamber, it is well to take off the cap, so that the gear-wheel can be seen during the operation. The pivot-point can then be taken out and the cups released by loosening the upper part of the shaft with a spanner wrench. This wrench is so designed that it can be used for loosening all parts of the meter.

In putting the meter together, first attach the cups to the cup shaft. In doing this, the upper part of the shaft should be inserted through the upper hole of the yoke before it is screwed to the lower part. Care must be taken to place the cups so that they will move counter-clockwise. After the cups have been fastened to the shaft, insert the pivot point and clamp it in place, and then insert the contact chamber. In replacing the contact chamber, the cups should be left free to move on the pivot point. Before inserting the frame nut, the pivot point should be adjusted and firmly secured with the lock-nut. The adjustment should allow a slight vertical motion of the cups.

TO CHANGE CONTACT CHAMBERS

1. Loosen the set screw to the contact chamber in place.
2. Carefully lift the contact chamber from the yoke.
3. Carefully unscrew either the worm, or eccentric, from the shaft and screw in the other, which will be found in the small round tin box.
4. Slide back in place the other chamber, which is in a block in one corner of the meter box, and tighten the set screw.

SPECIAL INSTRUCTIONS

Although the current meter is substantially made, and will stand considerable hard usage, it needs careful handling and attention to insure its proper working. In this connection the following instructions should be carefully observed:

1. Be sure that the set-screws are all tightened before putting the meter in the water; otherwise, some of the parts may be lost.
2. Loosen the raising nut and see that the meter runs freely before beginning a measurement. Spin the meter cups occasionally during a measurement to see that they are running freely, that is, that they will continue to move for a considerable time at a slow velocity.
3. See that the weights play freely on the stem, so as to take the direction of the current and thus avoid an unnecessary drag on the line.
4. If any apparent inconsistency in the results of an observation throws doubt on its accuracy, investigate the cause at once. Grass may be wound around the cup shaft; the cups may be tilted by tension on the contact wire; the channel may be obstructed immediately above the meter; the meter may be in a hole; or the cups may be bent so as to come in contact with the yoke.
5. After a measurement, it is absolutely necessary to pour out any water that may have collected in the commutator box, to clean and oil the bearings (in order to prevent rust) and to inspect the pivot point.
6. When the meter is not in use, the cups should never be permitted to ride on the pivot point.

7. Always see that the lock-nut on the pivot-point is screwed firmly against the frame nut, so that it will stay in place and carry the cups properly.

8. Never use a dulled pivot. Always keep several extra pivots on hand.

9. In measuring low velocities, be sure that the meter is in a horizontal position. If it has a tendency to tip, the balance weight on the tail should be adjusted or the meter be held rigidly by inserting a plug in the slot against the stem.

10. Avoid taking measurements in velocities of less than 0.5 foot per second, because the accuracy of the meter diminishes as zero velocity is approached.

11. For velocities of less than 1 foot per second, the pivot point should be the same as at the time of rating, sharp and smooth. As the velocity increases, the condition of the point is less important, because the friction factor decreases.

12. In taking measurements at high velocities, sufficient weight, and a stay-line, should be used to hold the meter in a vertical position.

13. In very shallow streams the meter should be suspended from the lower hole on the stem, and the weight should be placed above.

14. If the cups of the meter are bent, they may be easily put in shape by pressing them with a piece of wood or metal with a round, smooth end.

15. The telephone receiver is very sensitive to electric currents, and can be used to locate any break in the circuit. First try the telephone and battery together (Fig. 13) in a circuit having a make-and-break point, as at *a*. This may be done by using a knife blade or a screw driver, making connection where the wires enter the plug. If there is no click in

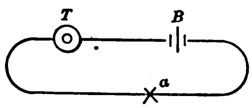


FIG. 13.

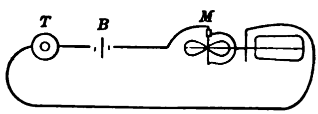


FIG. 14.

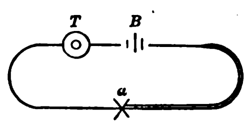


FIG. 15.

Testing Meter Circuit.

the telephone, then the battery or the telephone does not make a circuit. If there is a click, insert the meter in the line and test for a contact in the meter head (Fig. 14) by revolving the meter wheel. If the meter is all right, put the meter cord in the circuit and test both sides either by inserting a fine needle that joins both conductors or by making double connection and touching alternate sides of the line, *a*. (Fig. 15).

16. When the meter is not in use, disconnect the meter line from the battery, so that it will not become exhausted.

17. Do not strike the telephone receiver, as a heavy jar will to a greater or less extent, damagnetize the pole pieces, and to that extent will injure the receiver. If care is taken, it is very improbable that the telephone receiver will get out of order.

18. Care must be taken not to short-circuit the dry battery when the meter is not in use. To avoid this, the poles may be wound with adhesive tape.

RATING THE CURRENT METER

The relation between the revolutions of the meter cups and the velocity of the water may be determined by rating each meter before it is used. Theoretically, the rating for all meters of the same make should be the same, but, as a result

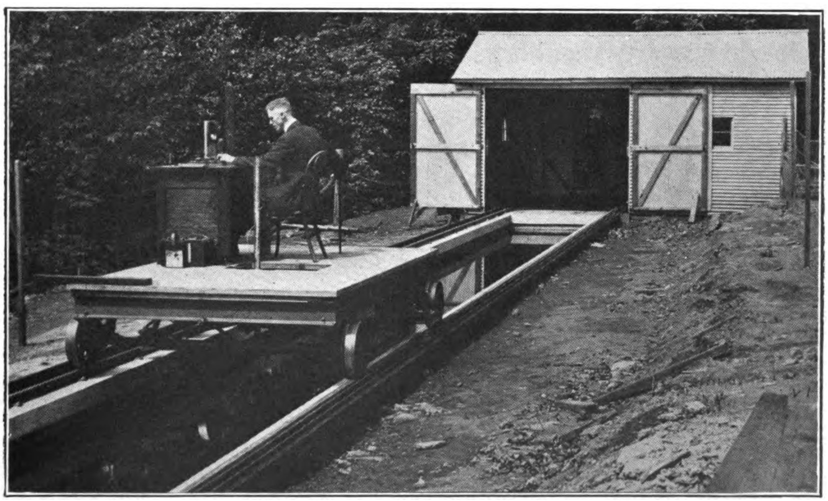


Fig. 16.— Current Meter Rating Station at U. S. Bureau of Standards.

of slight variations in construction, and in the bearing of the wheel on the axis at different velocities, the ratings differ slightly.

A meter is rated by moving it through still water with uniform speed, and noting the time, the number of revolutions, and the distance (Figs. 16 and 17). The revolutions per second and the velocity in feet per second are afterward computed from these data. Many runs are made, the speeds varying from the least which will cause the wheel to revolve to several feet per second. The results of these runs, when plotted with revolutions per second and velocity in feet per second as co-ordinates, locate the points which define the meter rating curve from which the rating table is prepared.

The number of revolutions of the meter wheel are indicated on an electric recorder; the distance is obtained by an electrical mechanism, which is in circuit with the meter wheel, so that the exact distance for a given number of revolutions is obtained; and the time is taken by a chronograph or a stop-watch, which is started and stopped by means of an electrical control.

Long experience has shown that with good care meters do not readily lose their adjustment. When used carefully, every day, in ordinary service, a meter should be rated once in three months as a check. Meters in similar service, but used less frequently, should be rated once a year as a check. For

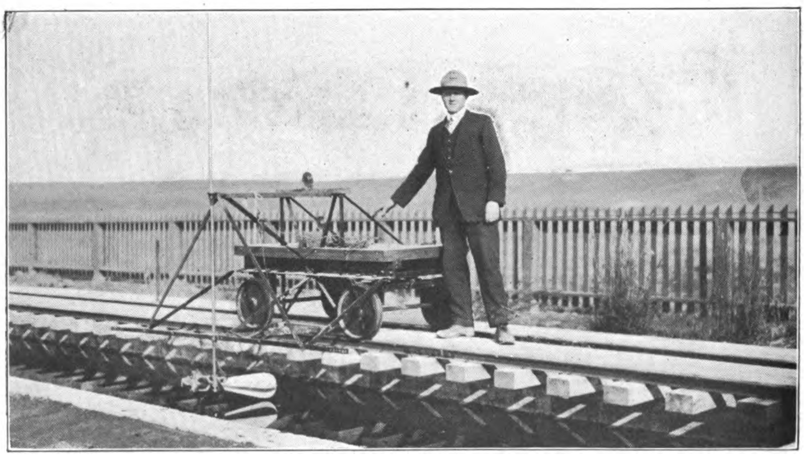


FIG. 17.—Current Meter Rating Station of Irrigation Branch, Canadian Interior Department.

special work the meter should be rated before beginning and as frequently as may be necessary during the work.

The details of rating a current meter and of preparing the meter rating curve and table are given in "River Discharge."* The rating should be done at a rating station, properly equipped to carry on the work. The rating station should be allowed ample time, usually about two weeks, to make the rating and to compute the rating table. The following table gives a list of rating stations and the cost of rating a meter:

STATION	ADDRESS	RATING FEE
U. S. Bureau of Standards,	Washington, D. C.	$10 for each head
Rensselaer Polytechnic Institute,	Troy, N. Y.	$10 " " "
Worcester Polytechnic Institute,	Worcester, Mass.	
Cornell University,	Ithaca, N. Y.	
University of Michigan, Naval Tank,	Ann Arbor, Mich.	
Imperial Valley Development Co.,	Calexico, Cal.	
University of Toronto,	Toronto, Ontario.	
Irrigation Branch, Department of the Interior,	Calgary, Alberta.	

Theoretically, the wheel of a differential-action meter, when carried through still water, should revolve as a wheel revolves in passing over the ground. That is, in going a given distance it should make practically the same number of revolutions, regardless of speed. The rating of a great many small Gurley electric meters shows this number to be from 42 to 44 revolutions in going 100 ft.

The true number of revolutions of the wheel should equal the distance of the run divided by the effective circumference of the wheel multiplied by a coefficient which depends on the retarding effect due to the pressure on the convex surface of the cups and their blanketing effect. Assuming the effective circumference to be the circle passing through the points of the cups, which is 0.7854 ft., and the true number of revolutions to be 43½ per 100 ft. run; then the coefficient would be 0.345. Although complete data are not available to confirm this theory, the working of the meter shows that it holds very closely to it.

The foregoing shows that the theoretical meter-rating curve is a straight line passing through the origin. If the true number of revolutions made in going 100 ft. is 43½, the

* "River Discharge", by Hoyt and Grover, for sale by W. & L. E. Gurley, price $2.00, postpaid.

equation of this curve will be X = 2.3 Y, where X = velocity, in feet per second, and Y = revolutions per second.

A study of the rating curves of a large number of small Gurley meters shows that, as a rule, the curve is made up of two straight lines, the extension of the lower one joining the upper one in an angle between the velocities of 8 and 9 ft. At this point there is a slight increase in the friction on the bearings of the meter wheel and shaft. Notwithstanding this break in the curve, the observed curve parallels the theoretical curve very closely. The lower part of the curve starts at a velocity of less than 0.1 ft. per second, which is required to start the wheel.

In using the meter, observation is made of the number of seconds the wheel requires to make a selected number of revolutions. Therefore, a rating table is prepared for each meter, giving the velocities per second corresponding to the number of revolutions. The most convenient table is prepared for 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, and 200 revolutions, with the times of the runs ranging from 40 to 70 seconds, giving velocities from 0.19 to 11.12 feet per second.

Reduction Table for Use with

Acoustic Current Meter, No. 616

This Table is a mean of the ratings of many different meters, and will probably give correct values within one per cent. for any meter of its pattern when in good order.

The time column is the number of seconds that have elapsed during one hundred revolutions of the wheel, there being ten revolutions to each rap.

Time	Velocity	Time	Velocity	Time	Velocity	Time	Velocity
1000	0.27	111	2.11	59	3.96	37	6.28
666	.39	105	2.22	57	4.08	36	6.51
500	.50	100	2.34	56	4.20	34	6.74
400	.61	95	2.46	54	4.31	33	6.98
333	.72	91	2.57	53	4.43	32	7.21
286	.83	87	2.69	51	4.54	31	7.44
250	.95	83	2.80	50	4.66	30	7.67
222	1.07	80	2.92	49	4.78	29	7.91
200	1.18	77	3.03	48	4.90	28	8.25
182	1.30	74	3.15	46	5.01	27	8.48
167	1.42	71	3.26	45	5.12	26	8.83
154	1.53	69	3.38	44	5.24	25	9.29
143	1.65	67	3.50	43	5.35	24	9.64
133	1.77	65	3.61	42	5.58	23	10.10
125	1.88	62	3.73	40	5.82	22	10.56
118	1.99	61	3.85	38	6.05	21	11.02

Reduction Table for Use with

Electric Current Meters, Nos. 617, 618, 621, 623 and 624

This Table is based on the ratings of many meters. The comparisons of the ratings of meters Nos. 617, 618, 621, 623 and 624, both penta recording and single point contact, show an agreement with this table within one per cent. Occasional ratings vary more than one per cent., when an individual rating table may be prepared.

[Extract from instructions given by the Water Resources Branch of the United States Geological Survey to their Hydraulic Engineers.]

Time in Seconds	VELOCITY IN FEET PER SECOND													Time in Seconds
	5 Revs.	10 Revs.	20 Revs.	30 Revs.	40 Revs.	50 Revs.	60 Revs.	70 Revs.	80 Revs.	90 Revs.	100 Revs.	150 Revs.	200 Revs.	
40	0.31	0.58	1.13	1.68	2.23	2.78	3.34	3.90	4.45	5.01	5.56	8.34	11.12	40
41	0.30	0.57	1.10	1.64	2.18	2.71	3.26	3.81	4.34	4.89	5.43	8.14	10.85	41
42	0.30	0.56	1.07	1.60	2.13	2.65	3.18	3.72	4.24	4.77	5.30	7.95	10.59	42
43	0.29	0.54	1.05	1.56	2.08	2.59	3.11	3.63	4.14	4.66	5.18	7.77	10.34	43
44	0.28	0.53	1.03	1.53	2.03	2.53	3.04	3.55	4.04	4.55	5.06	7.59	10.10	44
45	0.28	0.52	1.01	1.50	1.99	2.48	2.97	3.47	3.95	4.45	4.95	7.42	9.87	45
46	0.28	0.51	0.99	1.47	1.95	2.43	2.90	3.39	3.87	4.35	4.84	7.26	9.65	46
47	0.27	0.50	0.97	1.44	1.91	2.38	2.84	3.32	3.79	4.26	4.74	7.11	9.45	47
48	0.26	0.49	0.95	1.41	1.87	2.33	2.78	3.25	3.71	4.17	4.64	6.96	9.25	48
49	0.26	0.48	0.93	1.38	1.83	2.28	2.72	3.18	3.63	4.09	4.54	6.81	9.06	49
50	0.26	0.47	0.91	1.35	1.79	2.23	2.67	3.12	3.56	4.01	4.45	6.67	8.89	50
51	0.25	0.46	0.90	1.32	1.75	2.19	2.62	3.06	3.49	3.93	4.36	6.54	8.72	51
52	0.25	0.46	0.88	1.29	1.72	2.15	2.57	3.00	3.42	3.85	4.28	6.42	8.56	52
53	0.24	0.45	0.86	1.27	1.69	2.11	2.52	2.94	3.36	3.78	4.20	6.30	8.40	53
54	0.24	0.44	0.85	1.25	1.66	2.07	2.47	2.88	3.30	3.71	4.12	6.18	8.24	54
55	0.24	0.43	0.83	1.23	1.63	2.03	2.43	2.83	3.24	3.64	4.05	6.07	8.09	55
56	0.23	0.43	0.82	1.21	1.60	1.99	2.39	2.78	3.18	3.58	3.98	5.96	7.95	56
57	0.23	0.42	0.80	1.19	1.57	1.96	2.35	2.73	3.12	3.52	3.91	5.86	7.81	57
58	0.22	0.41	0.79	1.17	1.54	1.93	2.31	2.68	3.07	3.46	3.84	5.76	7.68	58
59	0.22	0.41	0.78	1.15	1.51	1.90	2.27	2.63	3.02	3.40	3.77	5.66	7.55	59
60	0.22	0.40	0.77	1.13	1.48	1.87	2.23	2.59	2.97	3.34	3.71	5.56	7.42	60
61	0.22	0.39	0.75	1.11	1.46	1.84	2.19	2.55	2.92	3.29	3.65	5.47	7.30	61
62	0.21	0.39	0.74	1.09	1.44	1.81	2.16	2.51	2.87	3.24	3.59	5.38	7.18	62
63	0.21	0.38	0.73	1.07	1.42	1.78	2.13	2.47	2.82	3.19	3.53	5.30	7.07	63
64	0.21	0.38	0.72	1.05	1.40	1.75	2.10	2.43	2.77	3.14	3.48	5.22	6.96	64
65	0.20	0.37	0.71	1.03	1.38	1.72	2.07	2.39	2.73	3.09	3.43	5.14	6.85	65
66	0.20	0.37	0.70	1.02	1.36	1.69	2.04	2.35	2.69	3.04	3.38	5.06	6.75	66
67	0.20	0.36	0.69	1.01	1.34	1.66	2.01	2.32	2.65	2.99	3.33	4.98	6.65	67
68	0.20	0.36	0.68	1.00	1.32	1.64	1.98	2.29	2.61	2.95	3.28	4.91	6.55	68
69	0.19	0.35	0.67	0.99	1.30	1.62	1.95	2.26	2.57	2.91	3.23	4.84	6.45	69
70	0.19	0.35	0.66	0.98	1.28	1.60	1.92	2.23	2.53	2.87	3.18	4.77	6.36	70

Reduction Table for Use with

Electric Current Meter, No. 600

This Table is a mean of the ratings of many different meters and will probably give correct values within one per cent. for any meter of its pattern in good order.

The observations of time should be made with a stop-watch and taken to a fraction of a second.

Time in Sec.	VELOCITY IN FEET PER SECOND												Time in Sec.
	5 Revs.	10 Revs.	20 Revs.	30 Revs.	40 Revs.	50 Revs.	60 Revs.	70 Revs.	80 Revs.	90 Revs.	100 Revs.	105 Revs.	
40	0.555	0.950	1.74	2.53	3.32	4.11	4.89	5.60	6.34	7.07	7.81	11.48	40
41	0.545	0.930	1.70	2.48	3.24	4.01	4.77	5.48	6.19	6.91	7.63	11.21	41
42	0.536	0.912	1.66	2.43	3.17	3.92	4.66	5.37	6.05	6.75	7.46	10.95	42
43	0.527	0.894	1.63	2.37	3.10	3.84	4.56	5.25	5.93	6.62	7.29	10.73	43
44	0.518	0.877	1.60	2.32	3.03	3.76	4.46	5.13	5.81	6.49	7.13	10.48	44
45	0.509	0.861	1.56	2.27	2.97	3.68	4.37	5.03	5.68	6.36	6.98	10.26	45
46	0.501	0.846	1.53	2.22	2.91	3.60	4.28	4.93	5.57	6.22	6.84	10.04	46
47	0.495	0.831	1.50	2.17	2.85	3.52	4.20	4.84	5.47	6.10	6.71	9.83	47
48	0.488	0.817	1.48	2.13	2.79	3.45	4.13	4.75	5.37	5.98	6.59	9.63	48
49	0.482	0.804	1.45	2.09	2.74	3.38	4.04	4.66	5.26	5.86	6.48	9.45	49
50	0.476	0.792	1.42	2.06	2.69	3.32	3.95	4.58	5.16	5.75	6.36	9.28	50
51	0.469	0.782	1.40	2.03	2.64	3.26	3.87	4.50	5.07	5.65	6.23	9.10	51
52	0.463	0.763	1.38	2.00	2.59	3.20	3.79	4.43	4.99	5.55	6.11	8.93	52
53	0.457	0 753	1.35	1.96	2.54	3.14	3.73	4.35	4.90	5.46	6.00	8.78	53
54	0.453	0.744	1.33	1.92	2.50	3.09	3.67	4.28	4.81	5.37	5.90	8.63	54
55	0.448	0.735	1.31	1.88	2.46	3.03	3.60	4.20	4.73	5.28	5.81	8.58	55
56	0.443	0.726	1.29	1.85	2.42	2.98	3.54	4.13	4.65	5.19	5.72	8.34	56
57	0.438	0.715	1.27	1.82	2.38	2.93	3.47	4.05	4.58	5.10	5.62	8.20	57
58	0.433	0.705	1.25	1.79	2.34	2.88	3.41	3.98	4.51	5.02	5.52	8.07	58
59	0.427	0.696	1.22	1.76	2.30	2.83	3.36	3.92	4.44	4.95	5.44	7.94	59
60	0.423	0.687	1.21	1.74	2.27	2.79	3.32	3.86	4.37	4.89	5.37	7.81	60
61	0.419	0.678	1.19	1.71	2.23	2.75	3.27	3.79	4.31	4.80	5.28	7.69	61
62	0.416	0.669	1.18	1.69	2.20	2.71	3.22	3.73	4.25	4.72	5.19	7.57	62
63	0.413	0.661	1.16	1.66	2.16	2.67	3.17	3.66	4.19	4.67	5.12	7.45	63
64	0.410	0.653	1.15	1.64	2.13	2.63	3.13	3.60	4.13	4.58	5.05	7.34	64
65	0.405	0.646	1.13	1.61	2.10	2.59	3.09	3.55	4.05	4.52	4.97	7.23	65
66	0.401	0.639	1.12	1.59	2.07	2.55	3.04	3.51	3.98	4.46	4.90	7.13	66
67	0.397	0.632	1.10	1.57	2.04	2.51	2.99	3.46	3.92	4.40	4.84	7.03	67
68	0.392	0.625	1.09	1.55	2.02	2.48	2.95	3.41	3.86	4.34	4.78	6.94	68
69	0.388	0.618	1.07	1.53	1.99	2.45	2.91	3.36	3.81	4.29	4.72	6.85	69
70	0.384	0.612	1.06	1.51	1.96	2.42	2.88	3.32	3.76	4.24	4.66	6.76	70

TYPES OF CURRENT METER MEASUREMENTS

There are three classes of current meter measurements in common use. They are named from the means employed by the hydrographer in reaching the measuring points, as follows: wading, cable, and bridge measurements.

Boat measurements are occasionally used (Fig. 18). The boats used for this work should be specially equipped so that all influence of the boat on the current measured is eliminated. Two ordinary boats may be quickly equipped at a small ex-

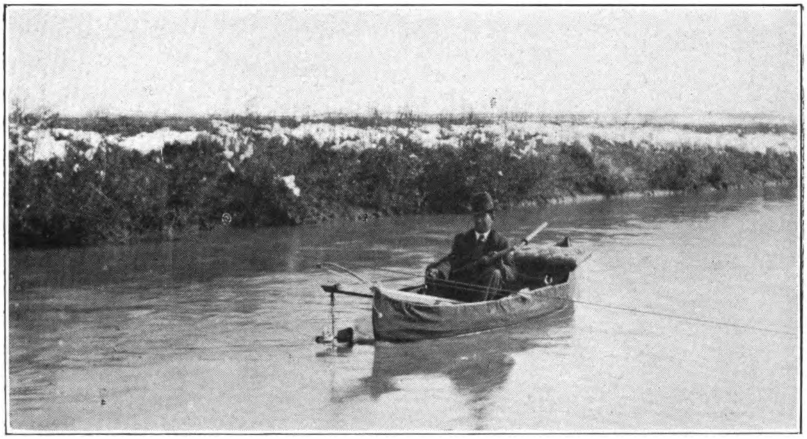


Fig. 18.— Boat equipped for Current Meter Measurements.

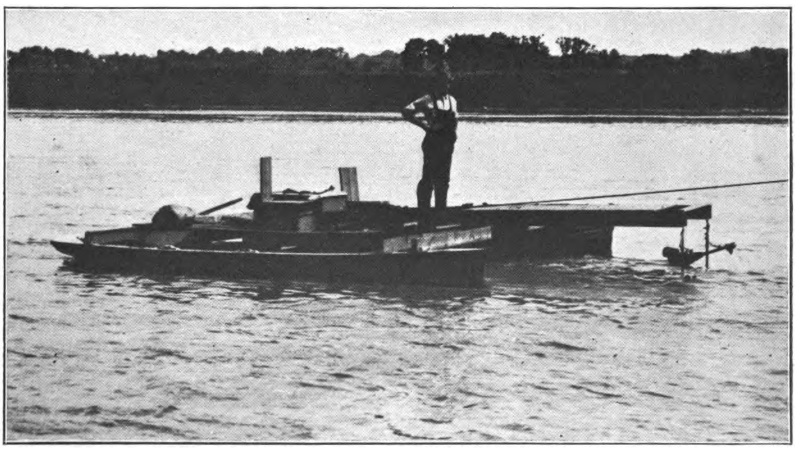


Fig. 19.— Catamaran equipped for Current Meter Measurements.

pense as a catamaran (Fig. 19), from which meters may be operated with great facility, in other than flood conditions. Precise results have been obtained in smooth water from a rig of this kind.

All measuring sections that are to be maintained continuously should have a fairly smooth bed, a uniform velocity of current not less than 0.5 foot per second at any stage, uniformly distributed throughout the section, with no strong eddies, cross currents, or boils, a permanent control assuring a constant relation between gage height and discharge, and should not be subject to marked fluctuations during the measurements. In changing conditions, the flow past the control is the essential factor, because the records of gage height and the rating table pertain to the section at the control, and not necessarily to the section in which the discharge measurements are made. A permanent reef or ledge extending across the stream (Fig. 20), a short distance below the edge, will control the relation between gage height and discharge, even though the bed of the measuring section itself may change. Where no natural control exists, an artificial control (Fig. 21) may be constructed. In general, it has been found more economical in the long run to make stream measurements where the conditions are permanent, even though the cost may be greater than if the measurements were made at a more easily accessible point, but with changing conditions.

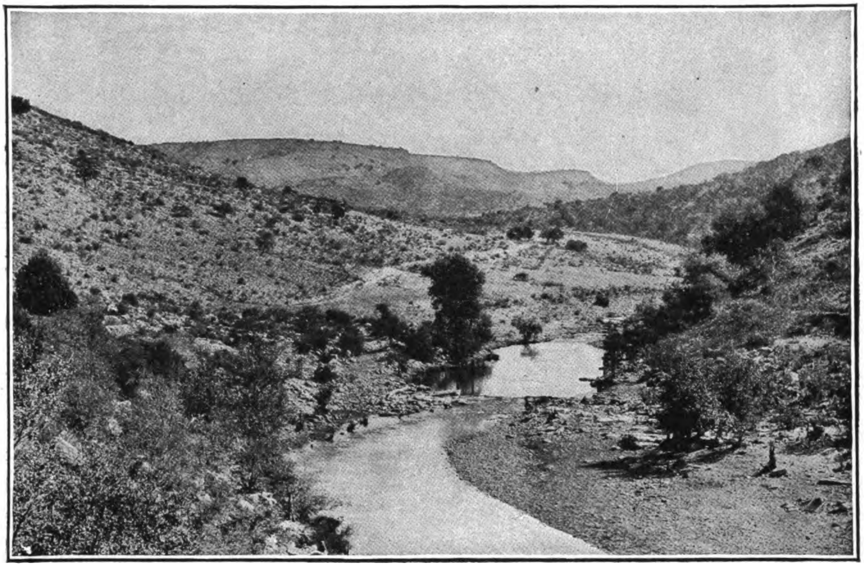


FIG. 20.— Natural Control of a Stream.

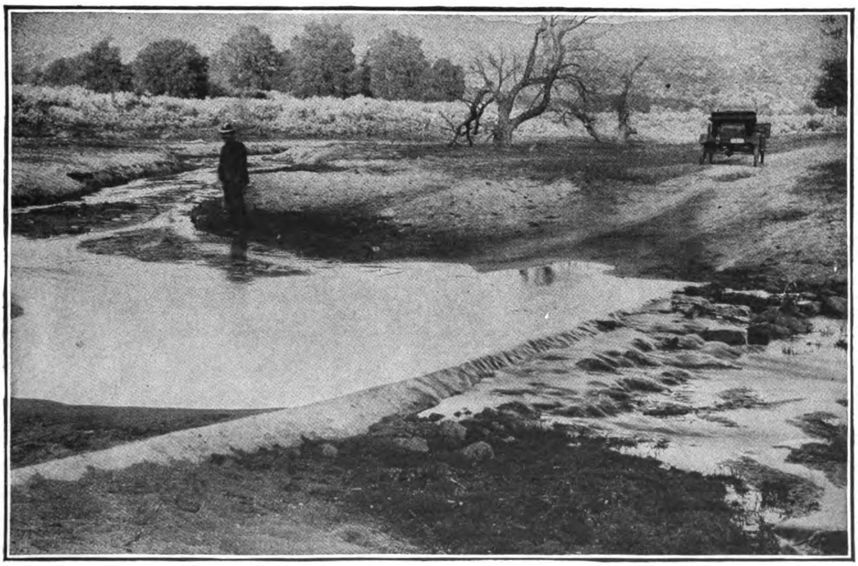


FIG. 21.— Artificial Control of a Stream.

WADING MEASUREMENTS

Measurements are made by wading (Fig. 22), wherever the depth and velocity of the stream permit the hydrographer to reach all measuring points and to hold the meter in position.

To mark the points at which observations are taken, it is customary to stretch a marking line across the stream. For this purpose a metallic tape may be stretched between iron rods that have slits in their ends; when there is a little wind, or for lengths not exceeding 200 feet, a braided silk fish line may be used. The line should be prepared for such use by marking it off while well stretched, into short lengths, say four feet each, with black paint, using special marks every 20 feet. When put in place for use the line is stretched until divisions are of the correct length when checked with a steel tape. For greater lengths a galvanized telephone wire, or a twisted smooth fence wire, may be used, the size of the wire being properly proportioned to the span.

The tape or the fish line which forms part of the hydrographer's kit is kept stretched across the stream only during the measurement, but wire markers are ordinarily left in place at the station.

Measurements should be made according to the condition of roughness of the stream bed. Under ordinary conditions the two-tenth and eight-tenth method should be used if the meter can be properly submerged for the upper measurements. In shallow water near the bank the six-tenth method may be used. If a stream is very shallow and its bed rough, the position of the thread of mean velocity may rise to one half of the depth. The hydrographer using the wading method can get his soundings accurately and can set his meter exactly at the proper positions. This method does not confine all measurements to a single section, but permits the hydrographer to select the most suitable section each time a measurement is made and is especially useful on small streams or at low stages. See page 51.

In making such measurements, the engineer should stand below the tape line and to one side of the meter (Fig. 23), in order that he may not disturb its action.

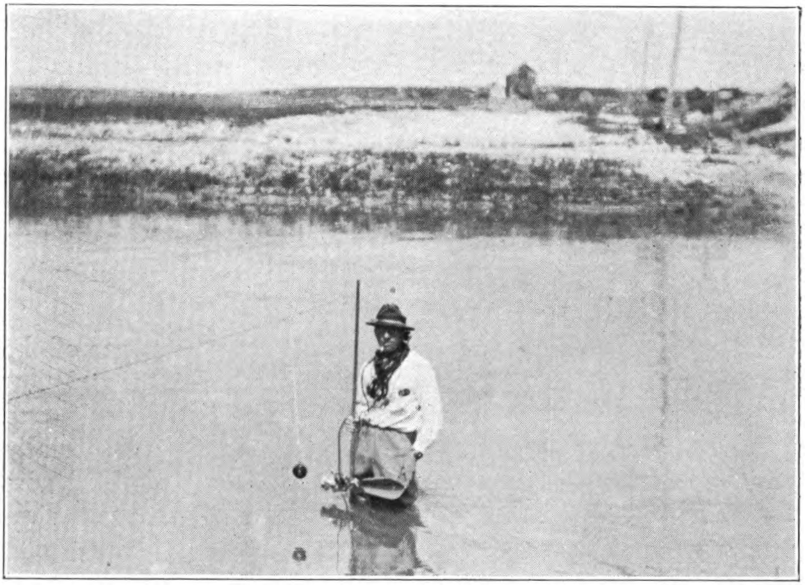


Fig. 22.—Wading Measurement.

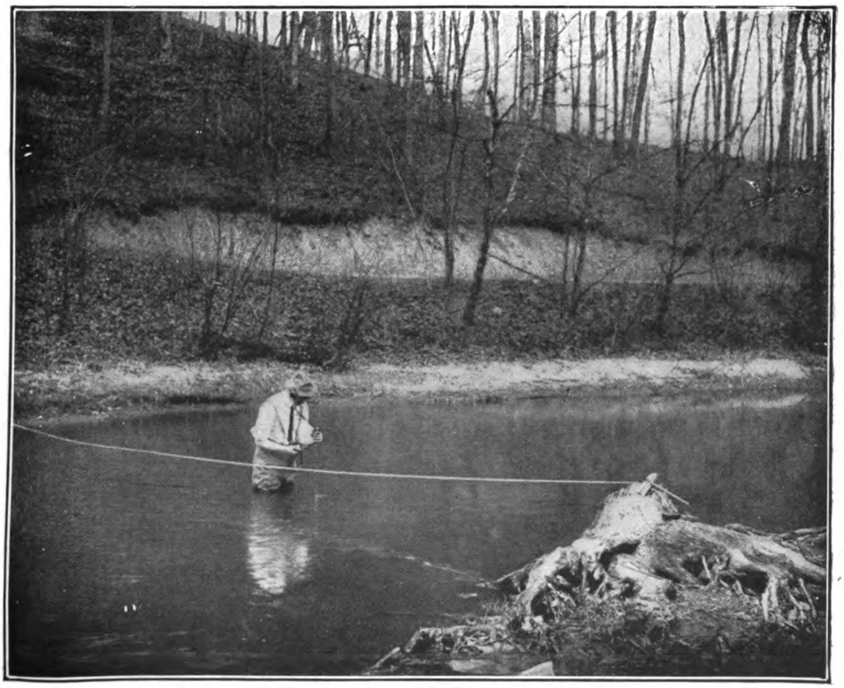


Fig. 23.— Typical Gaging Station for Wading Measurement.

MEASUREMENTS FROM CABLES

Cables (Figs. 24, 25, 26, 27, and 28), afford ready means of gaging streams up to a thousand feet in width, which includes most cases. The advantage in using a cable lies in the fact that the station may be placed at the most favorable location independently of existing structures. Complete details for installing cable stations are given in (U. S. Geological Survey) Water Supply Paper No. 371.

At cable stations the meter is suspended by means of the meter cable of No. 16 old code double insulated show window cord, which is thick enough to afford a comfortable grip and not cut the hands. A piece of twisted sash cord, or a specially prepared meter cord, carrying in the center an insulated wire and long enough to reach from the bottom of the stream to the surface of the water, is used between the top of the meter hanger and the meter cord in order to minimize the effect of the current. (See Fig. 1).

In swift water a head line is used to hold the meter in a vertical position. It is made of a piece of No. 10 galvanized iron wire, long enough to reach from the top of the meter hanger, to which one end of it is attached, to a rope above the surface. The rope is carried to pulleys on a stay line some distance up-stream, and back to the car. The hydrographer adjusts the stay line as required. (See Fig. 25).

At cable stations it is customary to use the two-tenth and eight-tenth method, taking the observation every 5 or 10 feet, according to the width of the stream.

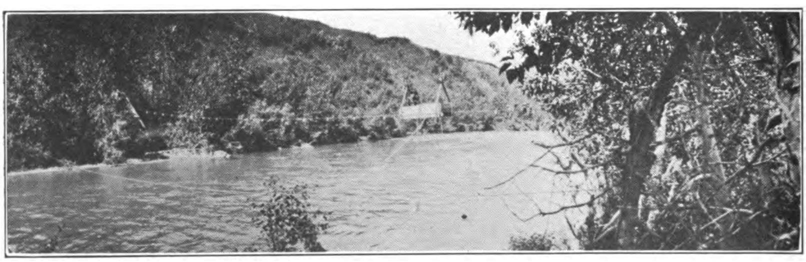


FIG. 24.—Current Meter Gaging Station.

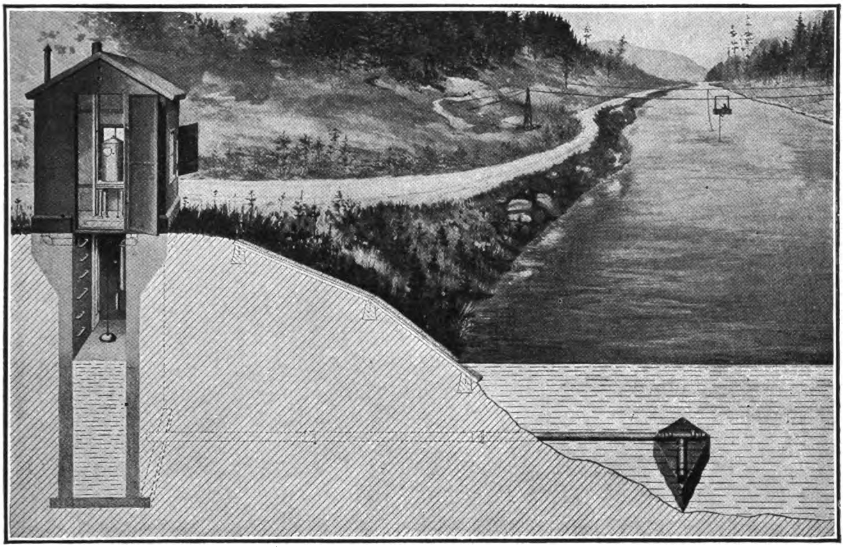


Fig. 25.— Typical Current Meter Gaging Station with Automatic Water Stage Register.

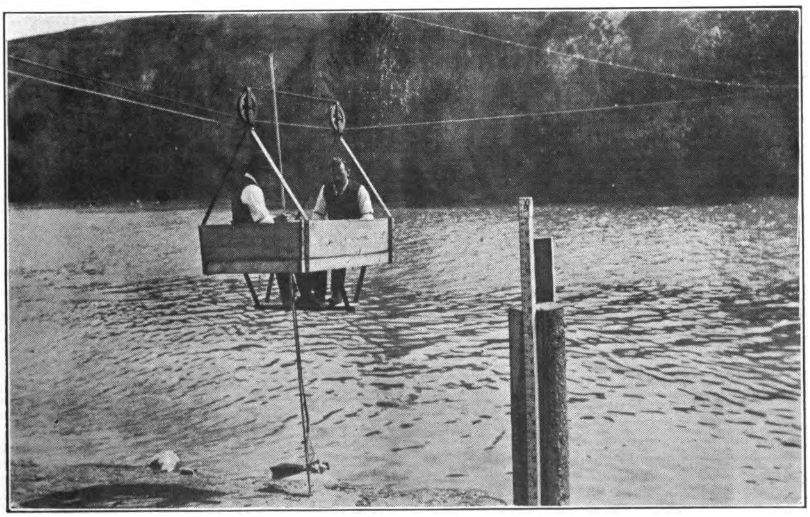
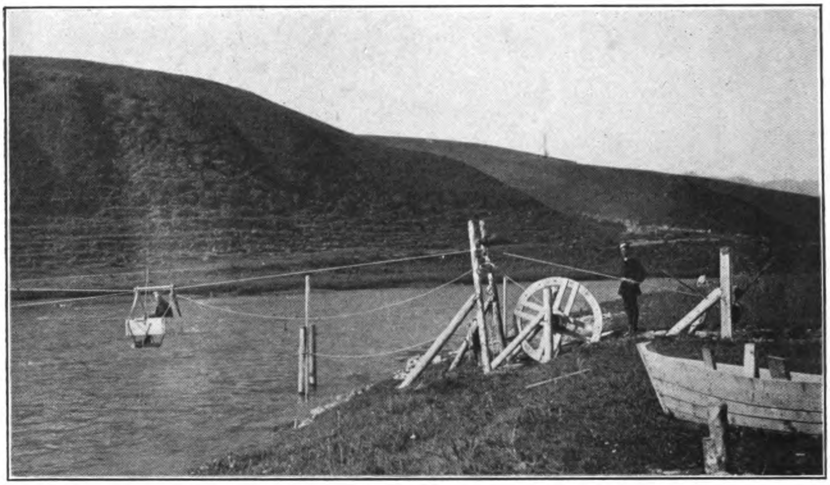
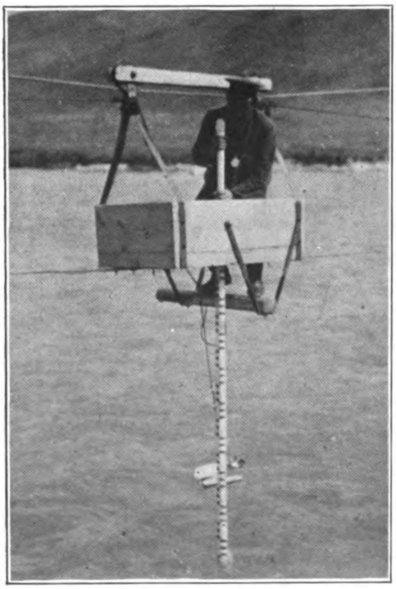


Fig. 26.— Current Meter Observers in Cable Car.





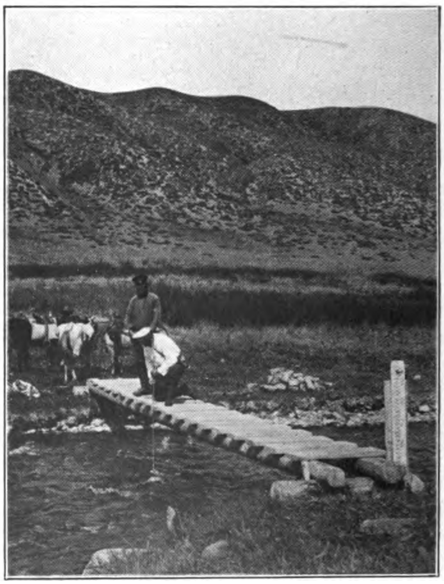


FIG. 27.—Russian Government Engineers using Gurley Current Meters in Turkestan.

MEASUREMENTS FROM BRIDGES

Occasionally bridges may be found well located as regards stream gaging. In such cases it is customary to mark off measuring points with paint on the rail or string piece of the bridge. The initial point of the series should be carefully referred to a permanent object and a careful description of the location written in the note-book.

A stayline is usually stretched above the bridge to be used when high velocities prevail. Measurements from bridges are made as from cables.

FIG. 28.— Typical Gaging Station for Bridge Measurement.

USE OF THE CURRENT METER

The quantity of water flowing in a stream is found by means of a current meter, by subdividing the cross-section of the stream into partial areas or panels and by multiplying each partial area by the mean velocity of the water that flows past each partial section, then taking the sum of all such products.

The cross-section of the stream is subdivided by verticals taken sufficiently close together to define the area accurately, as in cross-sectioning earthwork; that is to say, the lines (Fig. 28) on the stream bed between consecutive verticals should be essentially straight. On streams with smooth beds the points of observation will occur at regular intervals, but the method of computing the partial areas is not dependent on the distance apart of the verticals. The length of each vertical in feet is measured by sounding either with a sounding rod, using an engineer's level on the bank if desired, or by a weight and line.

The mean velocity in each partial area is the average of the velocities in the verticals that bound the area. Velocities are measured in feet per second; hence, the product of the partial area by the mean velocities will be in cubic feet per second. One cubic foot per second, is the quantity of water that will flow past a section of the stream one foot wide and one foot deep, with a velocity of one foot per second.

SOUNDINGS

Rods for sounding should be of a convenient length for handling and may be made either of wood or of metal. Wooden rods should be thin and sharpened on the edges, a section 3 inches wide and ¼ inch thick being appropriate for a length not exceeding five feet. Longer sounding rods may be made from 2 x 4 inch lumber, the edges being worked so that the cross section of the rod has the same shape as the hull of a ship. The correct style of metal rod (Figs. 4, 8 and 9) is furnished with all Gurley meters.

Where there is no danger of damaging the meter, the soundings are taken with the meter on the rod in all wading measurements. It should be noted that the zero of the graduations on the rods is at the center of the cups, so that a distance equal to the distance from the center of the cup, to the bottom of the

yoke should be added to each reading on the rod when sounding. In order to prevent the sounding rod sinking into the bed of the stream, it should be provided with a shoe at least 3 inches in diameter. When using the rod care should always be taken that the reading is not too high, on account of the impinging water running up the rod. If a sounding rod or line is used, the meter not being attached, the sounding are made at all measuring points before observing the velocities.

The soundings from bridges or cables are usually made with the weight and line, and in such cases, with swift water, a head line is used to hold the meter in a vertical position to prevent error, due to the weight being carried down the stream or to the bowing of the line. Soundings with the line are most readily taken as follows: The weight and line are lowered until the weight touches the bed of the river directly under the measuring point and, with the line taut, a point is marked on it by grasping it with the fingers opposite a fixed point on the bridge or car; the weight is then raised until it just touches the surface of the water and the length of the sounding line that passes the fixed point is measured. This length is measured by placing the end of a linen or metallic tape opposite the fixed starting point on the sounding line, grasping both the line and the tape in the hands, and drawing up the line and tape without permitting them to slip on each other until the weight reaches the surface of the water. The length of line thus drawn up, representing the depth of the water, is then read directly from the tape. This measurement can usually be made by one person with sufficient accuracy, even when the water is from 10 to 12 feet deep. On the U. S. Geological Survey standard cable car a scale is fixed to the frame of the car for measuring the depth.

VELOCITY OBSERVATIONS

In making a velocity measurement, the meter is held at the point in the stream at which it is desired to ascertain the velocity of the current. The wheel is allowed to revolve for a few seconds, in order that it may adjust itself to the current, after which the time for a given number of revolutions is noted, and the velocity is obtained from the rating table for

the meter. The run should be from 40 to 70 sec.; the number of revolutions observed, depending on the velocity of the water, should be one of those for which the meter rating table has been prepared. A check on the work is made by repeating the observation. If the run is not repeated, a check can be obtained by noting mentally the time for each five revolutions. A stop-watch is used for observing the time, and the record is made to the nearest ½ second. The observations should be recorded on properly prepared forms. See pages 54, 55, and 60.

In discharge measurements, the mean horizontal velocity in a vertical at the measuring point is desired. Various methods are used for this determination, among which the following four are most common: (a) Vertical velocity-curve method, (b) two-tenth and eight-tenth-depth method, (c) six-tenth-depth method, and (d) sub-surface method.

(a).—By the vertical velocity-curve method, measurements of horizontal velocity are usually made just beneath the suface, at 0.5 ft. below the surface, and at each fifth to each tenth of the depth from the surface to the bed of the stream, and as near the bottom as possible. These measured velocities, when plotted with depths as ordinates and velocities as abscissas, define for each vertical, the vertical velocity-curve which shows the velocity at every point in the vertical, and from which the mean velocity can be determined by dividing the area bounded by the curve, the top and bottom ordinates, and the axis of depth by the total depth. The area may be found by planimeter, or by Simpson's rule or Durand's rule*, which will be found in books on elementary mechanics.

Studies of vertical velocity-curves taken on many streams under various conditions of depth, velocity, and roughness of bed, show that these vertical velocity-curves have approximately the form of a parabola in which the axis, coinciding with the filament of maximum velocity, is parallel with the surface and is in general situated between the surface and one-third of the depth of the water. From the maximum the velocity decreases gradually upward to the surface and downward nearly to the bottom, where it changes more rapidly on account of the friction on the bed. As the depth and velocity

*Hancock, Applied Mechanics for Engineers.

increase, the curve approaches a vertical line as its limiting position.

The vertical velocity-curve method is valuable as a basis for the comparison of all other methods, for determining the coefficients to be used in reducing the values obtained by other methods to the true value, for use under new and unusual conditions of flow, and for measurements under ice.

(b).—In the two-tenths-eight-tenths method, observations of velocity are taken at two points located at depths of the surface of 0.2 and 0.8 of the depth in the vertical in which the measurement is made. The mean velocity is taken as the mean of the velocities at these two points. This method is based on the theory* that the vertical velocity-curve is a parabola, as already stated, in which case the mean of the ordinates at 0.2114 and 0.7886 depth below the surface gives the mean ordinate. This is mathematically true for any parabola and for any position of the thread of maximum velocity. A study of a large number of vertical velocity-curves shows that this holds true in Nature; and experience proves that this method gives more consistent results than any of the others except the vertical velocity-curve method.

(c).—In the sixth-tenth method, the observation of the velocity is taken at a depth from the surface equal to 0.6 of the depth of the stream. This method is also based on the theory** that the vertical velocity-curve is a parabola with the maximum abscissa between zero and one-third of the depth, in which case the mean ordinate is between 0.58 and 0.67 of the depth fom the surface. A study of a large number of vertical velocity-curve measurements shows that the mean depth of the mean velocity is approximately 0.6 of the depth. This method has the advantage of requiring a less number of velocity observations, and gives very satisfactory results, but not as good as those obtained by the two-tenths-eight-tenths method.

(d).—In the sub-surface method, the measurement of velocity is made at from 0.5 to 1 ft. below the surface, depending on the depth of the stream. The meter is held at sufficient

* See "River Discharge," page 54.

** See F. W. Hanna, M. Am. Soc. C. E., Engineering News, January 11, 1906.

depth to be out of any surface disturbance. When this method is used, the velocity must be reduced by a coefficient to obtain the mean velocity. This coefficient varies from 78 to 98%, depending on the depth and the velocity of the stream. The deeper the stream and the greater the velocity, the greater the coefficient. For average streams in moderate freshets, a coefficient of 90% should be used; in flood work, a coefficient of from 90 to 95%; and for streams at ordinary stages, from 85 to 90%.

Independent discharge measurements, as a rule, are of but little value in hydraulic work unless they are taken at stages which are known to be either extremely low or extremely high. In ordinary work it is necessary to make a series of measurements which, with daily gage heights of the flow of the stream, make possible the computation of the total flow of the stream and also its distribution. In connection with the individual measurements, therefore, it is necessary to observe gage heights and take full notes of the conditions under which the measurements are made, in order to enable the construction of a station rating curve and estimate the daily discharge.

RECORDING THE DATA

The observations should be noted at the time they are made on properly prepared forms for discharge measurements, shown on pages 54, 55 and 60.

There should be shown in these notes:

In column

1. The distance from the initial point of each vertical in which soundings and velocity observations were made. The distance between successive stations gives the width of the partial area. The widths are written in column 11.
2. The depth of water in the vertical at which the observation was made as determined by the sounding.
3. The depth from the surface down to that point in the vertical at which the velocity observation was made. This item is computed mentally in the field before making the velocity observation, and will be two-tenths, six-tenths, eight-tenths, etc., of the depth recorded in column 2, depending on the method used in making the measurement.

4. The duration of the velocity observation in seconds as determined by means of the stop-watch.

5. The number of revolutions of the cups in the time noted in column 4. For convenience in computing, the number of revolutions should be one of those appearing in the rating table for the meter used.

Computation of the quantities to fill in the remaining columns of the form are made as follows:

Column

6. Shows the velocity of the water as given by the meter at the point noted in column 3, and is taken from that column of the rating table at the head of which appears the number of revolutions shown in column 5, opposite the number of seconds noted in column 4. Columns 3, 4, 5 and 6 are completely filled in for each line on which an observation is noted.

7. The mean velocity in the vertical at any measuring point is the average of the velocity observations made in that vertical. When a single velocity observation is made in any vertical the value shown in column 7 will be the same as that shown in column 6.

8. To get the mean in the section, or partial area, take values for consecutive stations from column 7 and write their average in column 8.

9. The number of square feet in each section or partial area shown in this column is the product of the mean depth given in column 10, and the width as given in column 11, obtained from notes in column 1 as explained for that column.

10. The mean depth of each partial area is computed by averaging the depth (column 2) at each vertical with the depth (column 2) at the following vertical.

11. The width is the difference between the distances from the initial point of consecutive verticals.

12. The discharge for each section or partial area is the product of factors given in columns 8 and 9.

Not more than three significant figures should be used in the computations.

Columns 9 and 12 are added and the sum of the products in column 12 divided by those in column 9 to get the mean velocity in the entire cross-section. The mean velocity, total area and total discharge, are noted in the appropriate place on the form.

FORM NO. H-325.

FILE NO. { OFFICE........ FIELD ....

DISCHARGE MEASUREMENT NOTES.

Date..................................., 191..... No. of Meas......................

.... River at / Creek near ...., State of......................

Width.....................Area.....................Mean Vel.................. Cor. M. G. H.____________

Party.. Disch.____________________

Staff gage, checked with level and found..

Chain length, checked with steel tape, 12-lb. pull, found..............................ft.

" " changed to...............ft. at..............o'clock. Correct length......................ft.

" " corrected on basis of levels to.........................ft. at.........................o'clock.

Gage reading	Time	Station
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

Weighted mean G. Ht. ....ft.

Correct " " " ....ft.

Meter No..

Date rated..

Meas. began..............; ended....................

Time of meas. (hrs) ....Method...........

No. meas. sec's..............Coef..................

Av. width sec. ....Av. depth...........

G. Ht. change (total.) ....

...........% diff. by.....................rating table.

Meas. from cable, bridge, boat, wading. Meas. at............................ft. above, below gage.

If not at regular section note location and conditions...

....Area from soundings (date)..........................

Method of suspension...........................Stay wire...............Approx. dist. to W. S. ....

Arrangement of weights and meter; top hole.........; middle hole.........; bottom hole...........

Gage inspected, found................................ Cable inspected, found...........................

Distance apart of measuring points verified with steel tape and found...................................

Wind.....................upstr., downstr., across. Angle of current ....

Observer seen.............................. G. Ht. book inspected...

Examine station locality and report any abnormal conditions which might change relation of G. Ht. to disch., e. g., change of control; ice or debris on control; backwater from; condition of station equipment...

....

Sheet No. 1 of............sheets. If insufficient space, use back of sheet, with reference letters.

Fig. 28a.— Form No. H-325, Discharge Measurement General Data.

Form No. H-326.

DISCHARGE MEASUREMENT NOTES

Date..19............ No. of Meas..............................

.... River, at / Creek, near ....

Dist. from initial point		Depth	Depth of observat.	Time in seconds	Revolutions	VELOCITY			Area	Mean Depth	Width	Discharge
						At point	Mean in vertical	Mean in section				
Totals												

No...........of..........Sheets. Comp. by..................Chk. by..................Make notes on back.

Fig. 28b.—Form No. H-326, Current Meter Notes.

The preceding method of calculation may be summed up in the following expression:

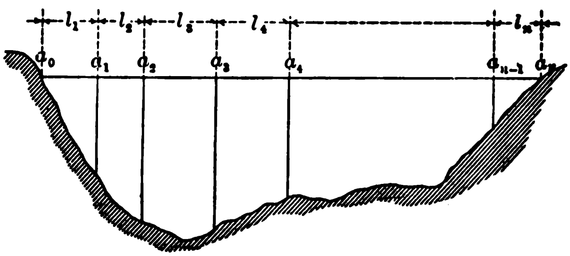


FIG. 29.— Cross-Section of Stream to Illustrate Discharge Measurement Computation.

$$D = l_1 \left(\frac{d_0 + d_1}{2}\right)\left(\frac{v_0 + v_1}{2}\right) + l_2 \left(\frac{d_1 + d_2}{2}\right)\left(\frac{v_1 + v_2}{2}\right) + \\ \ldots l_n \left(\frac{d_{n-1} + d_n}{2}\right)\left(\frac{v_{n-1} + v_n}{2}\right)$$

In this formula, d_0, d_1, d_2 .... d_n and v_0, v_1, v_2 .... v_n are the depths and velocities at the respective measuring sections a_0, a_1, a_2 .... a_n, which are spaced at the distances l_1, l_2, l_3 .... l_n, which is easily used as explained above and which gives accurate results.*

The field notes for each measurement, including a properly filled in copy of sheet 1, should be fastened together securely. This form, which is shown on page 54, should be filled in as soon as the field notes have been computed. The computations should be made before leaving the station. If the measurement does not plot within the limit of precision established for the work, the computation should be carefully reviewed and if necessary the measurement should be repeated.

It is of great importance to use the correct gage height when plotting a measurement. The gage height should be read at frequent intervals during the measurement, and the reading noted, together with the time. The vertical at which measurement is being made at the time of reading the gage should also be shown in the notes. At a recording gage station this distance from the initial point at which measurement is

*For a discussion of computation of discharge measurements by various formulas, see article by Mr. J. C. Stevens, M. Am. Soc. C. E., in Engineering News, June 25, 1908.

being made at even hours (or fractions thereof) if the stage is changing, is noted as the measurement progresses, and the corresponding gage heights are later taken from the automatic register. At non-recording stations, the gage height is noted similarly by reading either the gage itself, or else distances above or below a more conveniently placed reference point, whose index is in known relation to the gage height.

To give proper weight to the gage height readings, take the average of the first and second gage heights and multiply that average by the discharge that has been computed for that part of the cross-section between the vertical in which observation was made at the time of reading the first gage height, and the vertical corresponding to the time reading of the second gage height. Proceed similarly for the second and third gage heights, third and fourth, fourth and fifth, and so on, multiplying each average gage height by the corresponding partial discharge. Sum up all the products of average gage height and partial discharge and divide this sum by the total discharge as computed by adding up column 12. The quotient is the required weighted mean gage height.

LOW WATER MEASUREMENTS

At many stations the velocity of the river at low stages is so small that it may be advisable to find a section nearby in which the meter measurement may be made by wading.

Fig. 30.— Winter Measurement.

FIG. 31.

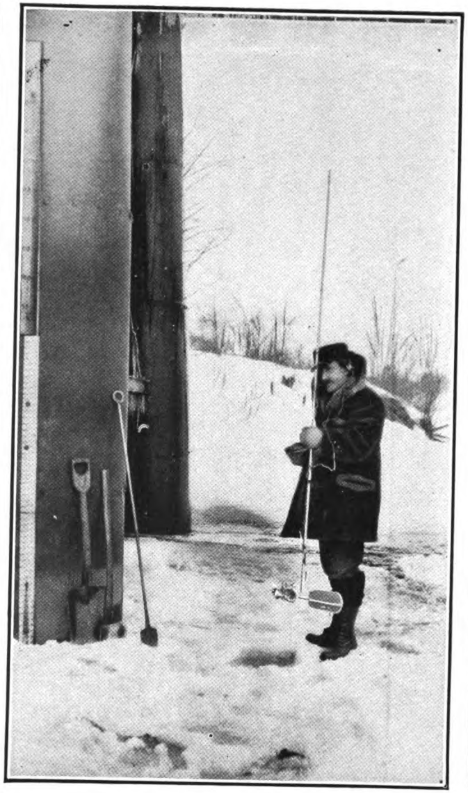


FIG. 32.

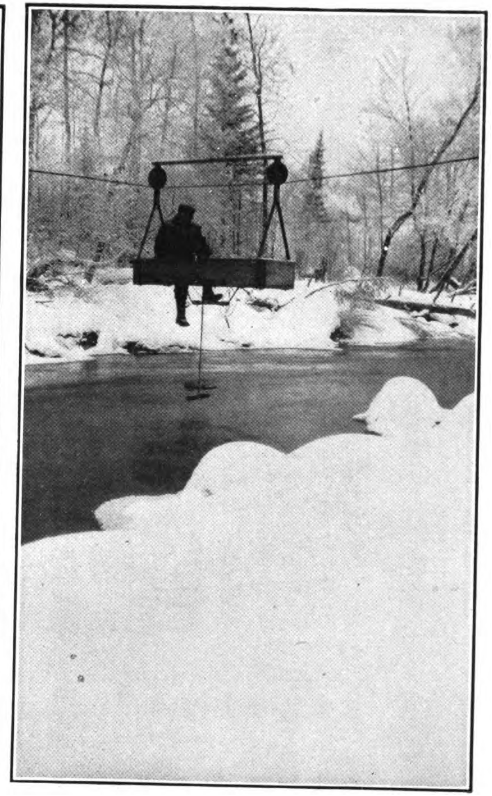


FIG. 33.

Current Meter Measurements in Winter.

For such measurements, the meter on the rod (Fig. 3) is the most satisfactory.

In order to obtain a suitable section, it may be necessary to cut off part of the flow by damming the stream and modifying the channel so as to get sufficient depth and velocity for measuring.

MEASUREMENTS UNDER ICE

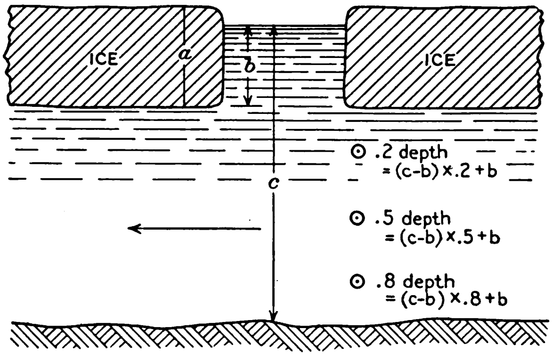
When a discharge measurement is to be made under ice, it is first necessary to find a good measuring section. Such a reconnoissance can best be made by a hydrographer who is familiar with the stream and who knows where he will find sections of the stream with smooth beds.

A hole is first chopped through the ice at the center of the stream at a section being investigated. If this hole shows that little or no slush ice is present, and the velocity is measurable, further investigations should be made at each side. It has been found that sections free of slush or anchor ice are most commonly found just above an open place on the river.

After the measuring section has been selected a hole is chopped through the ice at each measuring point, and the depth and velocity determined with the meter on the rod. Where the depth and velocity are too great the work will have to be done with the meter suspended on the meter cable.

Ice measurements are usually made by the .2 and .8 method, and sometimes by vertical curves. The soundings should be made to determine the depth from the bottom of the ice to the bed of the stream and the meter observations taken at .2 and .8 of this depth. In all other respects ice measurements are made and computed in the same way as open water measurements.

The special jointed ice chisel, ice-measuring stick and carrying bag, generally used in connection with ice measurements, are illustrated in Fig. 35.



OBSERVATIONS					
Distance from initial point	Thickness of ice / Water surface to bottom of ice	Total depth of water / Effective water depth	Depth of meter from water surface	Time in seconds	Revolutions
0					
10	*a*	*c*	(c-b)×.2+b		
	b	*c-b*	(c-b)×.5+b		
			(c-b)×.8+b		
15					

FIG. 34.—Diagram indicating notation used in making Discharge Measurements under Ice, with Form for Notes.

The notation and a form for recording the data are illustrated in Fig. 34.

The remaining seven columns are similar to those in Form No. H-326 (See page 55).

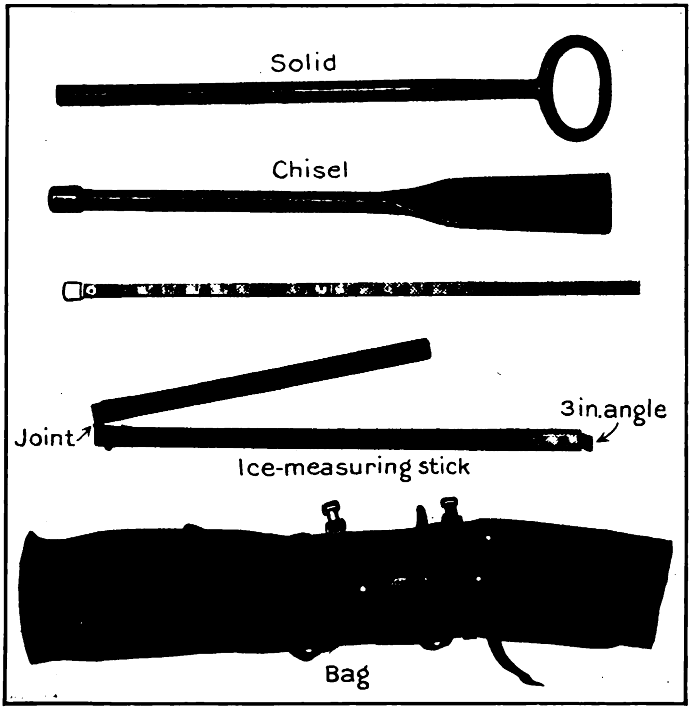


FIG. 35.— Ice Chisel, Ice Measuring Stick, and Bag.

FIG. 36.—Winter Measurement.

MEASUREMENTS IN ARTIFICIAL CHANNELS

Current meter measurements of the flow of water in artificial channels must be made with special care, as the laws of flow for open channels are not always applicable to artificial ones, because the water level may be subjected to disturbing influences such as undercurrents caused by intakes and outlets at rapid velocities.

Current meters have been employed in measuring the flow in large conduits. In such cases apparatus designed to hold the meter at a definite point in the cross-section has been used. The description of such apparatus will be found in the Transactions of the American Society of Civil Engineers, 1910, Vol. 66.

Current meters have also been used successfully for measuring the flow of sanitary sewers. Details of this work are given on page 130.

ACCURACY AND RELIABILITY OF THE CURRENT METER

When considering the accuracy of results obtained by the current meter, account should be taken of the use to be made of the data. It must be remembered that both the total flow of the stream and its distribution over the drainage area are constantly changing, and that the conditions over the drainage area are constantly changing, and that the conditions existing at any given time may probably never occur again. The flow which may be expected in any stream, therefore, can be determined only by studying a series of records extending over a long period; for this reason the degree of refinement with which the measurements are made should be appropriate to the use to which they are to be put.

As with most instruments, the accuracy and reliability of the current meter depend largely on the care taken in the measurement and the propriety of the method used.

SELECTION AND LOCATION OF GAGING STATIONS

RECONNOISSANCE

To obtain the best results with a current meter, stations should be located only at sites well adapted to its use. The same careful attention should be given to the selection of a current meter station as is given in establishing a system of control points for a topographic survey, in which case the entire problem is considered from all view points, only such control points being located as will give consistent and accurate results.

The final location of the gaging station and the choice of equipment to be installed will depend very largely on a thorough reconnoissance. This work is of equal, if not greater, importance than any other detail connected with the location of a gaging station. It should be performed by an engineer experienced in stream gaging work. Poor results obtained at many stations may be traced directly to the fact that such stations are not properly located.

When selecting and equipping a station, while considering the present use of the data to be obtained there, the importance of all possible uses for which the records may be required in the future, under changed conditions, should be kept well in mind, and all the requirements should be coordinated as completely as circumstances permit.

If the greatest immediate value of the data is for a power study in a given drainage area, locate at or near the center of the power zone a primary or base station, and elsewhere as many secondary stations as may be necessary. For this particular case, as in any other water supply problem, the base station should be placed at the strategic point on the main stream, and all data collected in the basin should be compared with the data obtained at the base station.

As the object of the reconnoissance is to find the best location that will furnish the desired data, it is well before locating the primary station to examine the locality carefully during various stages of flow, considering the stream under ice conditions, as well as during the summer season. At low stages the bed and the minimum velocity can be examined,

and some estimate of high water conditions can also be made, while at medium and high stages it is usually impossible to examine the bed or estimate low stage velocities. A stream in a lumbering section must be watched closely during the log-driving period. Locations at which log jams usually form should be avoided.

When the problem of locating stations involves an entire drainage basin, an hydraulic engineer familiar with the basin will likely have in mind tentative locations for the primary station and for supplementary stations, and will extend his reconnoissance by making examinations at different river stages at numerous points in the basin as he may have occasion to go back and forth in it. For locating secondary stations careful reconnoissances are also required, but they are usually made more rapidly.

If the project for which the data are collected depends on continuous flow, and there are few or no storage possibilities, the essential data will be that giving the amount of the minimum flow, and the period for which it continues. If opportunities for storage do exist, then the maximum flow will be of equal importance. Satisfactory results are usually obtained if these two extreme conditions are allowed to determine the location of the station.

The following essentials should be carefully examined:

1. The general course of the stream above, at and below, the station, noting whether the course of the stream is straight or whether curved.

2. The average depth and velocity of the stream at the section under consideration.

3. The character and location of the control point, with reference to the proposed location of the gage.

4. The character of the stream bed, whether of sand, gravel, boulders or rock, and especially whether it is shifting or permanent.

5. The character of the stream banks at the proposed section, whether high or low, clear or wooded, permanent or changing.

6. The relative position of dams and the mouth of tributary streams relative to the proposed location, consider-

ing carefully the effect of these on the gage heights and the measurements.

7. The availability of observers or attendants, and their qualifications for the work.

8. The most appropriate type of gage, whether recording or non-recording.

If no records are available concerning the diurnal fluctuations, such records should be secured at once by installing a portable automatic register (See Register No. 633, Fig. 50). The results of this test will show whether an automatic gage installation is necessary.

9. For an automatic water stage register, a survey of the location decided upon, to fix the character of the soil in which the well must be dug, the depth of the well, and the length of the intake pipe; for a vertical staff gage, the character of support available and the length of gage rod required; for an inclined staff gage, the character of the banks, the nature of the support for the gage, and its length; for a chain gage, the character of support available and the length of chain required.

10. The available or required structures from which to make measurements.

If a bridge, a general sketch of the vicinity showing especially high water lines, and a sketch of the bridge itself, showing the material of which it is built, the length and number of spans, and its height above water.

If a cable, the length of span, the kind and height of supports available or required, and the foundation available for them.

Some practical details* will be of assistance. The principal sources of error in gaging streams by current meters are due to the effect on the water stage of slack or nearly slack water in any part of the cross-section, to backwater from dams or other obstructions, or from tributaries, which may cause the river stage to rise without a proportional increase in discharge, and from obstructing ice. Do not choose a site immediately above or below the junction of two important branches. Fig. 37 shows a gaging station where the reconnois-

*These suggestions have been taken from a paper by C. C. Covert, M. Am. Soc. C. E., District Engineer, U. S. Geological Survey.

sance was hurriedly made, and where the gages were put in without any consideration to the effect of their location on the resulting records. The example given is that of two gaging stations on an eastern river, one on the east branch and the other on the west branch. From the gages to the junction of the two branches is approximately one and a half miles. The difference of elevation of the water surface at the two points is less than two feet at all normal stages. During high water periods there is always back water at one or both of the gages. While it is possible to determine the amount of back water, it would be expensive, and would have to be repeated at each successive flood, because the different conditions of flow produce different conditions of back water. On the west branch of the stream a chain gage was located near the center of a

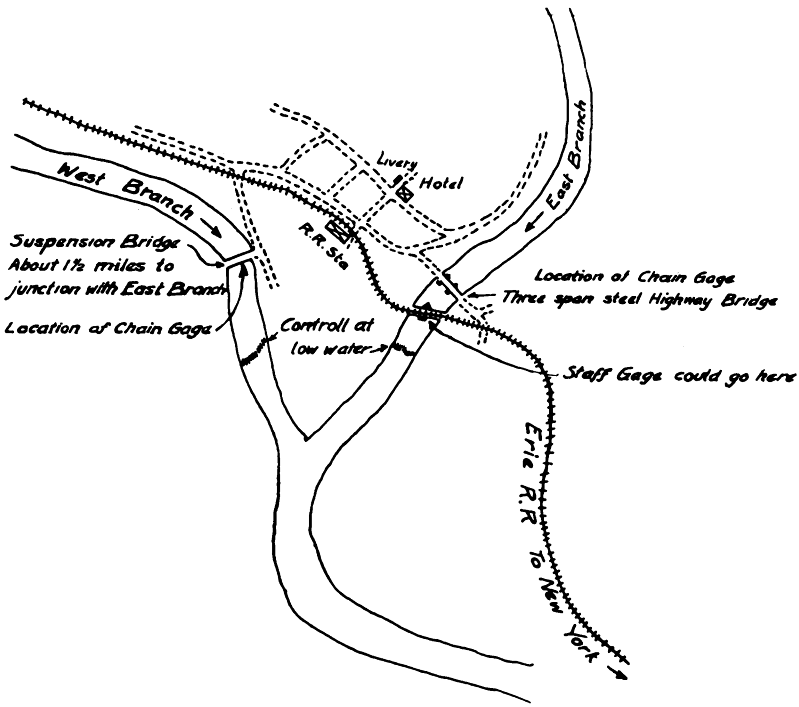


FIG. 37.— Showing poor location of Gaging Station, because of junction of two branches causing backwater. The location of gages at each station is also poor.

suspension bridge. This is an extremely bad arrangement. There may be considerable stretch to the chain, but the uncertainty as to the amount of rise and fall due to expansion and contraction of the suspension bridge is even more than the stretch of the chain. At this station there was an opportunity to anchor the chain gage to one of the towers and to install a staff gage on the rocks, the shore on the left side beneath the bridge being rocky and almost vertical.

At the station on the east branch the chain gage is used suspended from the upstream side of the highway bridge. A short distance below the highway bridge is a railroad bridge. This railroad bridge invariably causes back water at the highway bridge during the breakup of the ice. Had the gage at

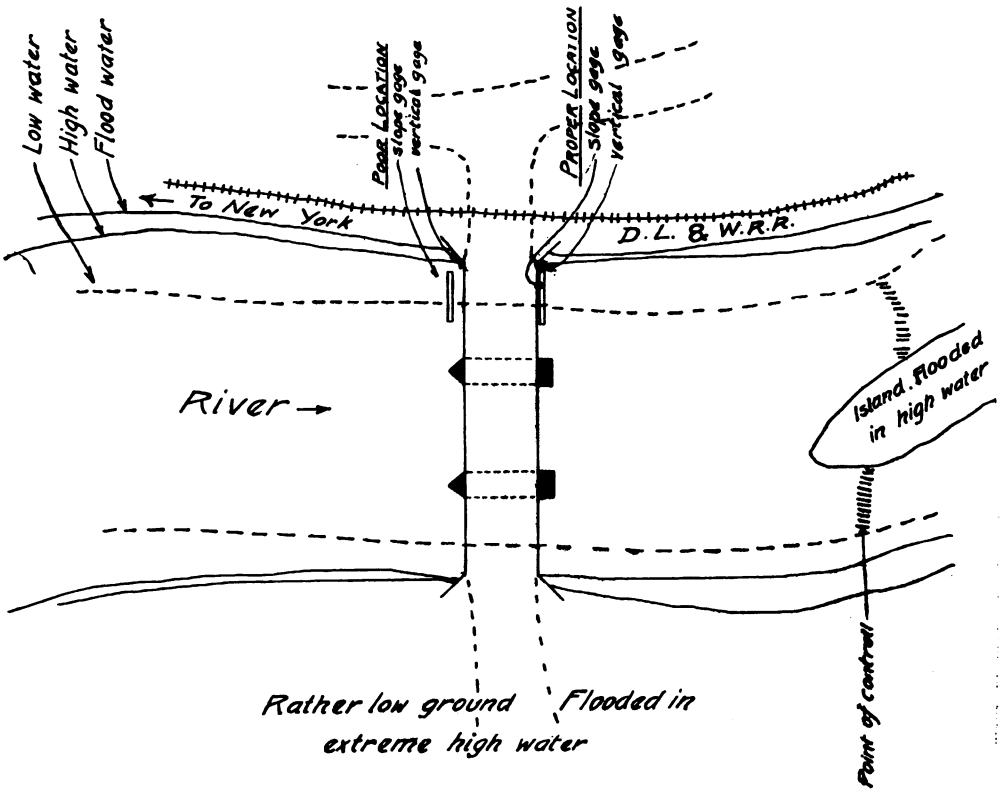


FIG. 38.— Showing proper and improper location of Gaging Stations.

this station been a staff gage and fastened to the downstream side of the railroad bridge, the records would never have been affected by the back water from either bridge, since the controling point for stream flow under natural conditions is 300 ft. or 400 ft. below the railroad bridge. The records would then have given much better results during the high stages.

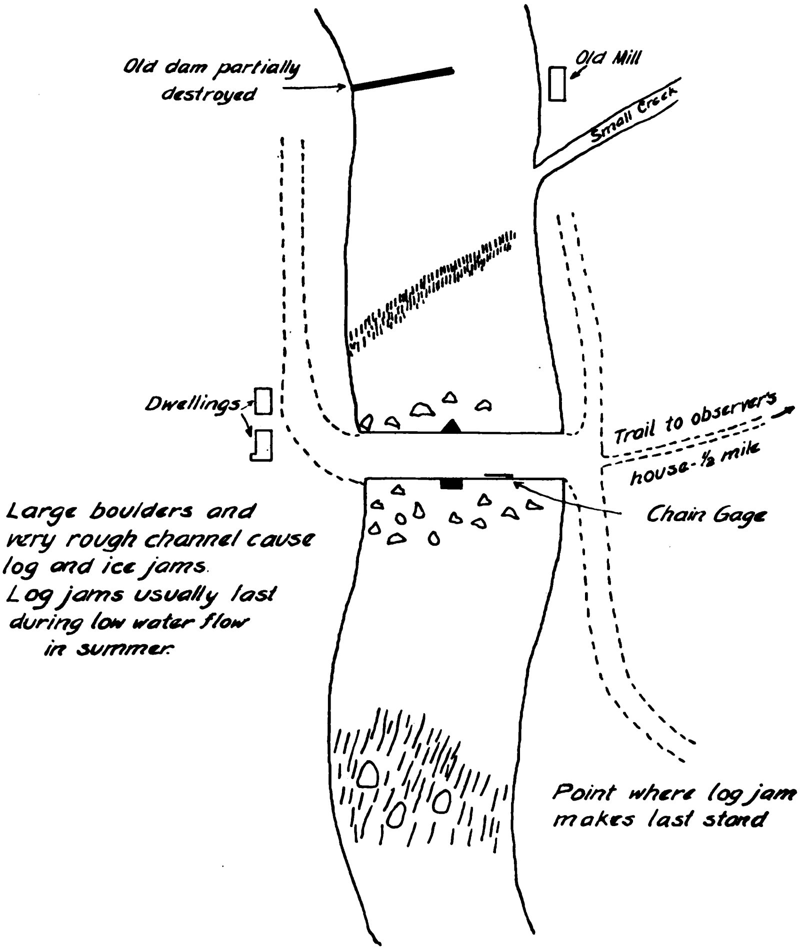


FIG. 39.— Showing poor location of Gaging Station due to channel conditions which cause periodic log and ice jams.

At another station a sloping staff gage was installed, about twelve feet upstream from the bridge abutment, Fig. 38. A vertical staff gage for high water period was installed on the upstream corner of one of the abutments. Thus, both of these gages are located so that if, for any reason, there are back water conditions at this bridge due to ice or logs jamming on the piers, the gage heights will be correspondingly affected. The proper procedure for installing these gages would have been to place the vertical staff gage on the downstream side of the abutment and to place the sloping staff gage for low water measurements in a line with the first gage. Had this been done, ice jams or any other back water conditions on the upstream side of the bridge would not affect the gage readings, while at the same time the vertical staff gage would have been protected from the ice and debris which floats in the stream during high water.

Fig. 39 illustrates another difficulty. In this case the gage was placed on the bridge because it was convenient, and also because the persons desiring the records were in a hurry for data and did not care to spend time and money on proper reconnoissance. The station was maintained four years. During the winter months it was always difficult to obtain measurements on account of ice conditions, and during the spring there were always log jams. The channel conditions were very rough and a portion of the log jams always remained during the summer months. In order to follow continually changing conditions it was necessary to make a large number of measurements at a correspondingly high cost for maintenance. Even with this done, the results obtained were only approximate. As many as four temporary curves were drawn and the exact period of each rating was uncertain. The operating cost for four years at this station was more than the entire cost of installation at the station eventually located two miles further downstream, at which accurate results were obtained at a low operating cost. At the last station there are some difficulties from ice conditions during Winter months, but it is possible with frequent measurements to overcome this in a satisfactory manner. In view of the lack of time at the start to give the river a thorough reconnoissance, it would

have been cheaper ultimately to have used a cable to overcome the poor channel conditions at the bridge.

In selecting a gaging station the judgment should not be unduly influenced by existing bridges or other convenient structures for supporting the gage, or from which measurements may be made. Better results will be obtained at smaller cost if these structures are ignored and the attention confined to the hydraulic features. The same mature consideration should be given the cost of operating the station as to the first cost of its installation.

OBSERVERS

The presence of a reliable observer is often a controlling factor in establishing a station. In many places this fact cannot be ignored, but where there is a choice the station should be placed at the most favorable location, and should not be subordinated to the convenience of the observer. The introduction of automatic registers which meet successfully all of the requirements at isolated places have solved many of the perplexing problems arising from the absence of observers at such stations.

ESTABLISHMENT OF STATIONS

After the reconnoissance has fixed the location and type of the station, its equipment is then installed. The most approved practice in the equipment of current meter gaging stations will be found in (U. S. Geological Survey) Water Supply Paper No. 371*, which may be obtained from the Director, U. S. Geological Survey, Washington, D. C., while the most approved methods of observing and preparing the data will be found in "River Discharge." **

Briefly, such stations for determining the total flow of a stream and its diurnal fluctuations need in general the following equipment:

1. A gage or gages to indicate or to record the fluctuations of stage.

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*Equipment for Current Meter Gaging Stations, by Geo. J. Lyon, M. Am. Soc. C. E.

**For sale by W. & L. E. Gurley, $2 net., postpaid.

2. Bench marks to refer the gages to a fixed datum, and to indicate whether the gages remain at the correct elevation.

3. Structures to protect the automatic water stage register when used.

4. Structures from which discharge measurements are made.

5. Stay line and head line to hold the meter in a vertical position when soundings and velocity observations are made.

6. Graduated lines to indicate the points of observation.

7. Structures to control and regulate the relation between stage and discharge at places where natural control is lacking.

Items 3 to 6 are illustrated in Fig. 25, which shows a typical gaging station, while item 7 is illustrated in Fig. 21. Full details are given in (U. S. Geological Survey) Water Supply Paper No. 371.

GAGES

The entire process of collecting stream flow data by current meter methods, is based on the constancy of the relation between gage height and discharge. Hence, the correct installation of the gage and its correct reading are fundamentally important. Errors in reading or recording the gage height are known to be the reason for the majority of inaccuracies in stream gaging work.

The instruments that have been used for indicating the elevation of water surface of rivers, lakes, and other bodies of water may be grouped into two general classes, comprising respectively non-recording gages and recording water stage registers, the grouping depending on the method of obtaining the record, whether by direct readings by an observer at stated intervals from a scale board, or other device, or by some automatic mechanism.

NON-RECORDING GAGES

Non-recording gages in common use are the vertical or inclined staff gage, the hook gage, the chain gage, and the float gage.

The staff gage, whether vertical or inclined, is the most satisfactory non-recording gage for all ordinary conditions. In many cases it is possible to read staff gages more accurately if a stilling box is used. A small box without a cover, and with

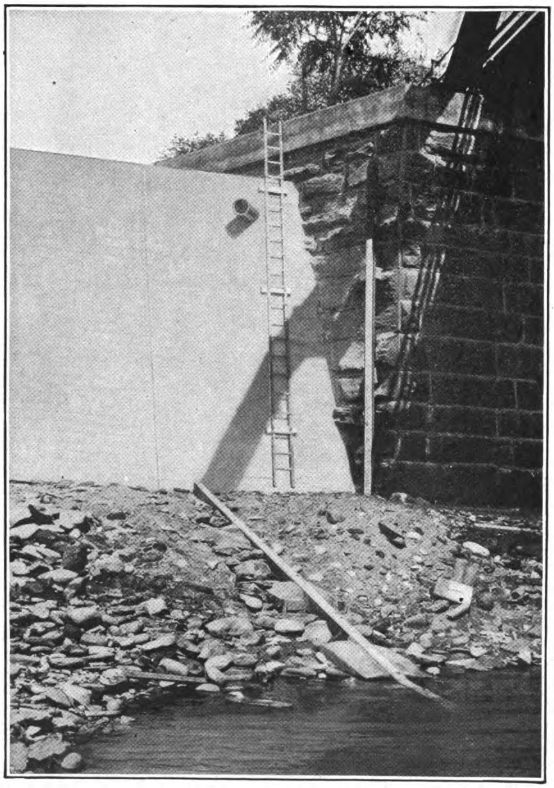

FIG. 40.—Vertical and Inclined Staff Gages.

one end removed, just wide enough to slide along the bedpiece, makes an excellent, simple device for this purpose. The box turned upside down, is placed on the gage each time it is read, being stored above high water when not in use.

In some situations, two gages (Fig. 40) are desirable, one for low and the other for high water.

Hook gages are used in stream gaging work in the wells where automatic registers are installed, or elsewhere for special investigations.

Gurley Hook Gage

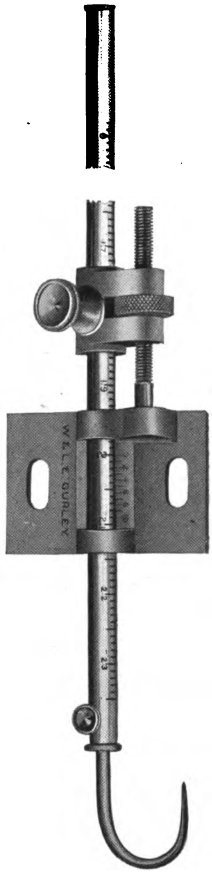

Fig. 41.— No. 628 Hook Gage.

This new type of Hook Gage is a great improvement over other patterns. Its entire arrangement is such that the readings can be taken by the observer with the greatest possible convenience and at some distance from the surface of the stream or ditch being measured. This is often a decided advantage, especially so in the East, where many of the streams are contaminated by dye stuffs and other undesirable material, rendering it unpleasant for the observer to get too close to the water.

The Hook Gage is made entirely of metal and is nickel plated throughout. The tube is regularly made to read to 2.2 feet but may be made longer if desired. It is graduated to feet, tenths and hundredths, and is read to thousandths by a vernier, which is capable of fine adjustment by means of a slow motion screw. Elongated holes in the base furnish means for bolting the gage to the side of the flume. The hook is adjustable within the tube and allows for a movement of 12 inches independent of the gage, thus permitting it to be set accurately to the exact surface of the water.

TO USE THE GURLEY HOOK GAGE

The hook gage is used in a box attached to a flume at any convenient point near the weir, the water from the flume being conveyed to the box by rubber or lead pipes, thus indicating the precise level of the water in the flume, the surface of the water in the box being at rest.

When the depth of the water passing over a weir is required, the exact level of the crest of the weir should be taken by a leveling instrument and rod, and marked by a line drawn

in the still water box at the surface of the water. The scale of the gage being previously set at zero with the vernier, the base is fastened to the box above the water in a vertical position and at such a height that the point of the hook is at the same level as the crest of the weir, the precise point being secured by moving the hook in the tube. The point of the hook will of course be under water and level with the crest of the weir.

The depth of water flowing over the weir is the distance between the point of the hook in the position named and the exact surface of the water. To ascertain this, the hook is raised by turning the milled head nut until the point of the hook, appearing a little above the surface, causes a distortion in the reflection of the light from the surface of the water. A slight movement of the hook in the opposite direction will cause the distortion to disappear, and will indicate the surface with precision. The reading of the scale will then give the depth of water passing over the weir, in thousandths of a foot.

It will be understood from the illustration that the longer movements of the scale are made by loosening the large clamp screw and sliding the graduated tube through the frame, the finer adjustments being made by the milled nut.

Floating gages to record only maximum and minimum stages are used occasionally where such information is sufficient.

Chain gages may sometimes be used in situations where no other type could be installed. Great care should be taken to secure a rigid support for a chain gage.

All gages should be placed so that they may be easily read. The scales of non-recording gages should be divided into feet and tenths. When it is desirable for the ordinary gage reader to read closer than tenths of a foot, the tenths should be divided into halves and quarters rather than into hundredths. Experience has shown that the ordinary observer is able to read common fractions of a tenth more readily than decimal fractions. Where skilled observers are available the decimal system may be used.

To insure accurate marking, all gages should be subdivided, either by means of a steel tape or an engineer's level. The zero of all gages should be accurately referred to a fixed datum, and the relation thus established should be checked frequently by means of an engineer's level.

RECORDING WATER STAGE REGISTERS

Recording water stage registers make a record of stage, either continuously by a curve, the coordinates of which indicate the time and the stage, or by a device that prints at stated intervals of time. The essential parts of the recording gage are: (1) A float which rises and falls with the surface of the water; (2) A device for transferring the vertical motion of the float to the record, either directly or through a reducing mechanism; (3) The recording device; and (4) The clock.

Gurley recording water stage registers are described in detail on pages 77 to 117.

BENCH MARKS

The value of all streamflow records depends so intimately upon the constant relation between zero of the gage and the station bench mark that too much care cannot be taken to insure the permanence of this relation.

Two independent bench marks at each station are desirable. They should be so located that they will not be damaged by floods or other causes. At bridge stations at least one bench mark should be apart from the structure. Where trees are available, a track spike with the front edge of the head upturned, makes a useful bench mark. In a locality without timber the United States Geological Survey type bench mark (Fig. 42) is available. To set it, dig a hole of small diameter with a post hole digger, well below frost line. Place in the

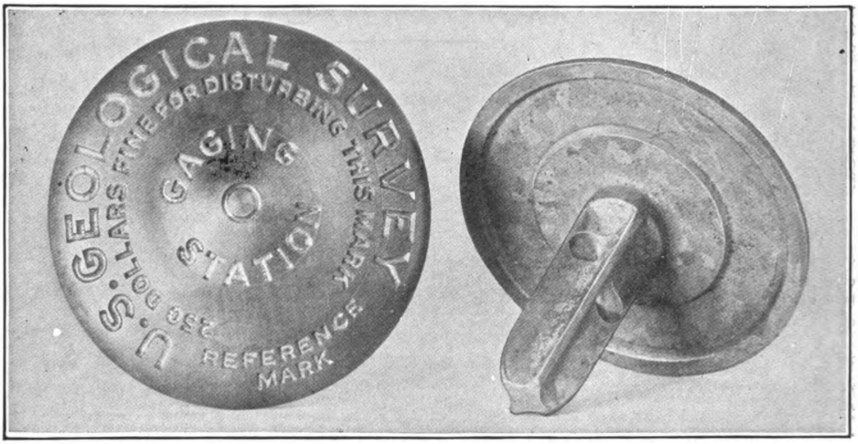

FIG. 42.— United States Geological Survey Bench Mark.

hole a piece of 3-inch pipe and fill the hole with concrete; fill the pipe with cement mortar, into which set the bench mark tablet. Always place the tablet with the axis of the stem vertical, so that the circle marking the elevation is actually the highest point of the bench mark.

Avoid placing bench marks on new or unstable structures. Wherever possible, place the bench mark so that the gage may be reached in one set up.

Having established the station bench mark, its location with respect to prominent objects should be carefully described. While in some cases it may be desirable to know the elevation of the gage datum above sea level, much confusion will be avoided if an arbitrary elevation, applicable to all emergencies and future conditions, is assigned, and only that elevation used in station descriptions.

PART II.

GURLEY AUTOMATIC WATER STAGE REGISTERS THEIR CONSTRUCTION, INSTALLATION AND OPERATION

INTRODUCTION

For the purpose of obtaining continuous records of stream flow, it is necessary to establish and to equip permanent stream gaging stations and to observe and tabulate certain data.

For each gaging station, a station discharge table showing the discharge corresponding to all gage heights within the range of stage is prepared. The relationship between gage height and discharge remains constant as long as the control is unchanged, so that as long as the gage heights are accurately read and carefully recorded the data obtained will be accurate.

The discharge of uniformly flowing unregulated streams at well selected gaging stations may be obtained by applying to the station discharge table two daily gage heights per day, of which one is usually taken in the morning and the other in the evening. But such gage heights read morning and evening will not take account of sudden increases in stage due to floods, or to those due to regulation of the flow. To take account of such variations, including those incident to power regulations of the stream, which materially affect the estimates of run-off (sometimes affecting the monthly means as much as 30 per cent.), it is necessary to install automatic water stage registers. It is also highly desirable, and in many cases, as a matter of record, is essential, to use them at any station from which the records are to be used as a basis of proportioning the stream flow among a number of users, as in power, irrigation, and mining practice.

CONDITIONS REQUIRING THE USE OF AUTOMATIC WATER STAGE REGISTERS

The conditions requiring the use of automatic registers have been admirably discussed in detail by the Engineers of the United States Geological Survey.**

**By Mr. Glenn A. Gray, M. Am. Soc. C. E., District Engineer, in a paper before a Conference of Engineers of the Water Resources Branch, U. S. Geological Survey, Washington, D. C., December, 1914.

By Mr. C. H. Pierce, M. Am. Soc. C. E., District Engineer, in Contributions to Hydrology, 1915, Water Supply Paper 375-F, U. S. Geological Survey.

It may be said that automatic water stage registers are necessary:

1. Where water is valuable and exceptionally accurate records are necessary.

In irrigation enterprises information concerning the quantity of water that can be supplied is necessary to interest capital, and the accuracy of the stream-flow records will determine not only the feasibility of a project, but in a large measure the future of the community interested. Recent development in the West has created a demand for water, and the quantity available must be accurately measured before the water subject to filing or the quantity in excess of prior rights is known. Owing to lack of stream-flow data, many streams are over appropriated by water users. Often the discharge of the streams on which such conditions exist is small and difficult to measure. In determining the flow of a stream subject to additional appropriation of water, the automatic register is absolutely necessary.

2. Where the artificial or natural conditions on a stream cause sudden changes in stage during the 24-hour period.

Sudden changes in stage due to natural conditions may occur, on streams draining areas of high altitude and fluctuating with melting and freezing snows. A stream subject to change because of the climatic conditions may show great variation in stage within the 24-hour period, especially during the spring or when the mountain snows are melting, the effect depending to a certain extent on the distance between the gaging station and the mountainous section of the drainage area. At a station in the mountains and near the source the stage generally increases during the day and decreases at night; at a station farther from the source or mountainous section the time of increase or decrease in stage varies according to the distance. Reservoirs storing stream water for use as occasion demands, either for power or for irrigation, or both, produce artificial conditions that may cause sudden changes in stage. To obtain an accurate record of changes in stage irregular in intervals and unequal in magnitude, and also of the quantity of water released from storage reservoirs as well as of the flow not stored, an automatic register is essential.

3. WHERE RECORDS ARE DESIRED ON A FLOOD-WATER STREAM WHICH IS DRY MOST OF THE YEAR.

Records of flow of a flood-water stream whose channel is dry most of the year are very difficult to obtain. Streams of this type carry water at times of melting snow or of heavy rainfall. The rain may come in the form of a cloud-burst and the floods resulting are of short duration, perhaps 15 or 20 minutes. Even if a staff gage and a gage reader were available, the flood would pass the gage before the reader arrived there. The duration of the flood depends largely on the size and character of the drainage area and the distribution of the rain fall. An automatic register is necessary if a true hydrograph of the stream is to be obtained. The float of such a register is usually carried up with great force and rapidity when the wall of water or bore of the flood, sometimes 15 or 20 feet high, reaches the register. Much foresight must be used to prevent damage to the automatic register from such sources.

4. WHERE COMPLETE RECORDS ARE DESIRED ON A STREAM WHICH FLOWS CONTINUOUSLY BUT IS SUBJECT TO SUDDEN FLOODS.

The flow of a perennial stream that is not subject to floods can be accurately determined by readings from a staff or chain gage; but a stream subject to sudden floods can not be accurately gaged without automatic instruments. Not uncommonly the gage reader at a station where a staff or chain gage is used makes two readings daily—morning and evening. If a heavy rain occurs between the time of these two readings and causes a sudden flood it is more than probable that the morning and afternoon gage heights will give no indication of the change in stage, but will simply show a constant discharge. Since a large proportion of the total run-off from a basin occurs at times of flood, a true index of the flood-flow must be obtained. Conditions stated under 3 and 4 are similar, in that flood waters furnish a large proportion of the total run-off.

5. WHERE IT IS NECESSARY TO DETERMINE THE MAXIMUM GAGE HEIGHT OR THE MAXIMUM DAILY MEAN GAGE HEIGHT.

The necessity for a record showing maximum gage heights or the maximum daily mean gage height arises principally in connection with the design of power dams and bridges. If a stream is subject to frequent floods during the year and the maximum gage height must be determined, a continuous hydro-

graph for 365 days is necessary. The peak of a flood can be ascertained by observation of the driftwood at the gaging station but a record of its duration would not be available unless constant attention was given by the gage reader. If the maximum daily mean gage height is desired, the hydrograph from an automatic register is even more essential. The mean obtained from a staff or chain gage read twice daily might indicate a different day of maximum from that shown by automatic recording register. The day of maximum gage height is not always the day of maximum daily mean gage height. Two daily readings might indicate several days during a year as days of maximum mean gage height, within a small per cent of each other, whereas an automatic register record would doubtless show entirely different results. The accuracy required for such data would, of course, play an important part in the selection of the type of gage, but for a record which would be beyond question an automatic register is necessary.

6. WHERE IT IS NECESSARY TO DETERMINE THE MINIMUM GAGE HEIGHT OR THE MINIMUM DAILY MEAN GAGE HEIGHT.

The necessity for a record of the minimum gage height or minimum daily mean gage height occurs in connection with water power and irrigation practice. The minimum flow of a stream in amount and duration is one of the controlling factors of a water power project, and the duration of the period of flow should always be determined with accuracy. In some places flood water may be stored to replenish the low flow; a continuous record should, therefore, be obtained to determine the amount of storage required. In irrigation projects the low-water flow is not so essential unless the low-water period occurs in the irrigation season and the quantity of water required is in excess of the supply.

7. WHERE SMALL STREAMS OF SUDDEN FLUCTUATION ARE MEASURED BY WEIRS FOR ADJUDICATION OF WATER BY THE COURTS.

The mean of three or four readings per day of the head on a weir may give an erroneous result, especially when the stream is subject to fluctuation. To properly obtain the mean head on the weir for the 24-hour period an automatic register should be installed a sufficient distance above the crest of the weir to avoid the effects due to the curvature of the approaching water.

8. WHERE THE AVAILABLE GAGE READERS DO NOT HAVE SUFFICIENT INTELLIGENCE TO READ A GAGE OR CAN NOT BE TRUSTED.

9. WHERE THE STATION IS SITUATED AT AN ISOLATED POINT AND A GAGE READER IS NOT AVAILABLE.

The necessity for establishing a station at an isolated point, where a gage reader is not available, has caused the installation of many automatic registers. Many stations are 50 to 100 miles from a railroad in regions whose inhabitants have no fixed abode. This condition affects the collection of data for irrigation projects less than for water powers. Irrigation lands are in general not so remote from habitations as water power sites. At several stations in the West valuable stream flow data could not have been collected had the continuous automatic water stage register not been invented.

ESSENTIAL FEATURES OF AUTOMATIC WATER STAGE REGISTERS

Automatic recording water stage registers consist of:

(1) A float that rises and falls with the surface of the water.

(2) A mechanism that transfers the vertical motion of the float to the record, either in natural or reduced scale.

(3) A sheet of paper on which a record of the rise and fall of the float is made.

(4) A clock.

(5) A cover for the instrument.

The essential features of a good automatic register are:

(1) A float of sufficient area to be sensitive enough to respond quickly to a change in water stage, connected to a counterweight by means of a perforated band that is positive in its action.

(2) A transfer mechanism so carefully made that it performs all of its functions with certainty and precision.

(3) A record sheet that is not distorted by moisture and that gives the record in a form most appropriate to the use to which it is to be put. This involves the cost of handling the records, including provision for filing them, and of the office work incident to applying the gage heights to the discharge table.

(4) A weight driven clock, of heavy yet simple construction, with a refined escapement, compensated for temperature.

THE FLOAT

The value of records from water stage registers varies with their accuracy, which is limited in large measure by the readiness with which the instrument responds to slight changes in the height of water. Precision in recording depends directly on the amount of power required to operate that part of the mechanism which records the water stage at any given instant, as well as upon the time element. This power is obtained from the bouyant, or lifting force, of the water acting on the area of a float, that is connected by means of a perforated band to a counterweight. The band passes over the driving wheel of the recording mechanism between the float and the counterweight. The band itself should be as light in weight as possible, consistent with its required strength and life. The counterweight should weigh somewhat more than the total weight of the band and a weight sufficient to overcome the friction of the instrument, if suspended from the counterweight side of the driving pulley of the recording mechanism. Likewise, the float should weigh somewhat more than the combined weights of the tape, the counterweight and a weight sufficient to overcome the friction of the instrument if suspended from the float side of the driving pulley.

The cross-sectional area of the float parallel to the water surface determines the power of flotation, the readiness of response to slight variations in water stage, and the amount of power available to operate the recording mechanism. The area of the float parallel to the water should be as large as possible in order to get a maximum amount of displacement, and hence bouyancy and power, for each fraction of an inch of the vertical height of the float.

When an instrument is installed over the well, the float and counterweight together with the bouyant force of the water, will assume a relation of balance or equilibrium; that is, the weight of the counterweight and band on its side of the driving wheel will equal the combined weight of that portion of the float that is above the water surface and the band on the

float side of the driving pulley. If no power was required to operate the instrument, then a condition of balance would always be established immediately after any change in the elevation of the water surface and the driving wheel would turn an amount equal to the change in rise and fall.

Since it is impossible to construct a frictionless instrument, or in other words, one that would require no power to operate, it is necessary to provide the required power. That is done by disturbing the relation of balance between the float and the counterweight, mentioned above, by an amount equal to a weight sufficient to drive the recording mechanism. The overbalance is due to the rise or fall of the water around the float, and the instrument will not respond until such rise or fall of the water on the float forms a water column of the cross-sectional area of the float and equal in weight to the force required on the rim of the driving wheel to operate the instrument. It will readily be seen that for a given weight the altitude of this water column, (which is the rise or fall of the water surface) must be greater for a small cross-sectional area than for a large cross-sectional area. Hence the same instrument will be more sensitive, with a corresponding increase in the refinement in the record, when a large float is used than when a small one is used.

Since the area of the float parallel to the water controls the sensitiveness of the register, it is interesting to note the following comparison of the weights of circular columns of water one hundredth of a foot (0.12″) high for various diameters. These computations show the relative power derived from floats of different diameters. It will be noted that the power of the float varies as the square of its diameter.

Diameter of float in inches	Area of float in square inches	Inches in 1/1000 foot	Volume of water column in cubic ins.	Weight of 1 cubic inch of water in ounces	Power of weight of water column in ounces
4	12.57	x0.12	1.51	0.58	0.88
6	28.27	0.12	3.39	0.58	1.97
8	50.26	0.12	6.03	0.58	3.50
10	78.54	0.12	9.43	0.58	5.47

In Gurley water stage registers the power required to operate the recording mechanism is reduced to a minimum, but to insure precision and certainty of action a large float is always used.

THE TRANSFER MECHANISM

The range of the time-keeping mechanism may be definitely decided upon for any type of register. Hence, if the movement along either axis of the register must be limited the time axis may be of fixed length. Such is the case in Gurley registers of the graphic type, on which the records are changed at fixed intervals of time. On printing type registers, however, the time is transferred to the record from the faces of cylindrical type wheels, which revolve with the hands of the clock continuously for as long a time as may be desired.

The range of water stage, on the other hand, may be decidedly variable. Hence, on graphic registers the axis along which the record of stage is made should not be limited in length. For this reason the record of stage should be made around the circumference of the cylinder on the register. Since it is possible for the cylinder to revolve on its axis, such an arrangement of the axis of the record allows any change of stage, no matter how great, to be recorded, each complete revolution of the cylinder corresponding to a definite change in stage. On the printing type registers the record of stage is printed on the continuous record tape by cylindrical type wheels, and these are made so that they may make any necessary number of complete revolutions.

All parts of the transfer mechanism, including the lead screws that move the pencil carriage, the perforated bronze band connecting the float and the driving pulley, and all gears, should be so accurately constructed as to be free from lost motion.

THE RECORD SHEETS

Record sheets for graphic registers should have accurately printed on them a time scale and a water stage scale. The point of the pencil is the index for time and water stage when adjusting the record sheets. These record sheets are shown on pages 116 and 117.

The record sheet, for printing type registers, is a strip of paper 1¼ inches wide, a roll of which is placed on one reel and received on another, after having passed over the tvpe wheels where it has printed upon it the water stage to hundredths of a foot and the time of record. Between the record paper and the type wheels runs a strip of carbon paper the same width as the

record paper and carried in the same manner between the type wheels and the record paper, the carbon face being next to the record paper. When the printing hammer strikes, a carbon impression is made on the white record paper.

The printed type of record has these advantages: the relation of time and gage height is in no way affected if moisture changes the width or length of the tape, and it is a kind of record that may be understood by commissioners or attorneys without engineering training.

THE CLOCK

A weight driven clock compensated for temperature is the most desirable type of time keeper for a water stage register. In order to get extra long bearings for the shafts of the clock gears the front and back plates of the clock should be heavier than in an ordinary time piece. The lower wheels that carry the heavy weights should be fitted with phosphor bronze bushings and the shafts themselves should be of highly polished steel, these metals being the most suitable combination for such purposes. The adjustment of the mesh between the escapement and the clock train should be perfect. This relation is permanently maintained by hardening the end of the escapement shaft and using a sapphire bearing jewel. The escapement must be so arranged that it may be thrown out of mesh with the clock train to make it possible to set the clock to the proper time without changing the relation between the time type wheel (5), the clutch (11), and the hands. (See Fig. 47, page 91).

THE COVER

A tight fitting cover should enclose all automatic recording registers so as to exclude dirt from the mechanism. Dust or grit settling on the gears and bearings of any time piece soon interferes with its satisfactory operation.

TYPES OF GURLEY AUTOMATIC WATER STAGE REGISTERS

Gurley automatic water stage registers are divided into two classes — those making a printed record, and those making a graphic record. In the printing type a simultaneous record of water stage and time is made; in the graphic type the record is made continuously, by a curve, the coordinates of which indicate the time and the stage. Both classes of registers will be described in detail.

Frequency of record of stage and time. This is the only register that records automatically a printed record of stage to hundredths of a foot and of time to fractions of an hour.

Continuity of record. This register will operate continuously as long as the clock weight which is lowered 1½ inches in 24 hours is free to fall in the well. Registers have frequently operated for six months with one winding. The driving weights may, however, be raised whenever required without moving the cover or in any way interfering with the operation of the register.

Absence of moisture effects. The record is made by printing figures on a strip of paper and is independent of the size of the strip. The accuracy of the record is unaffected by any changes in the size of the strip of paper due to varying conditions of moisture.

Unlimited record of stage. A change of stage is recorded by means of the revolution of the type wheels of the recording mechanism. These are free to revolve any number of times with the change in stage and may do so without confusing the record.

Singleness of interpretation and permanence of record. The record of both time and stage is printed directly on the record paper in permanent form. Printed figures have only one meaning and hence the interpretation of the record is not susceptible to any variation due to personal equation. These considerations are of great importance where the figures are likely to become part of a court record.

Convenience in changing records. The record papers may be changed at any time. It is not necessary to change them at stated intervals. This makes possible the use of this type of register in inaccessible places.

Simplicity of record. The printed record is a form easily interpreted by those without technical training. The reduction of the record is a non-technical clerical operation. It is greatly facilitated by the use of a tape reel. (See Fig. 46).

Superior mechanical execution. Every part is made of properly selected material finely finished to insure accuracy in operation.

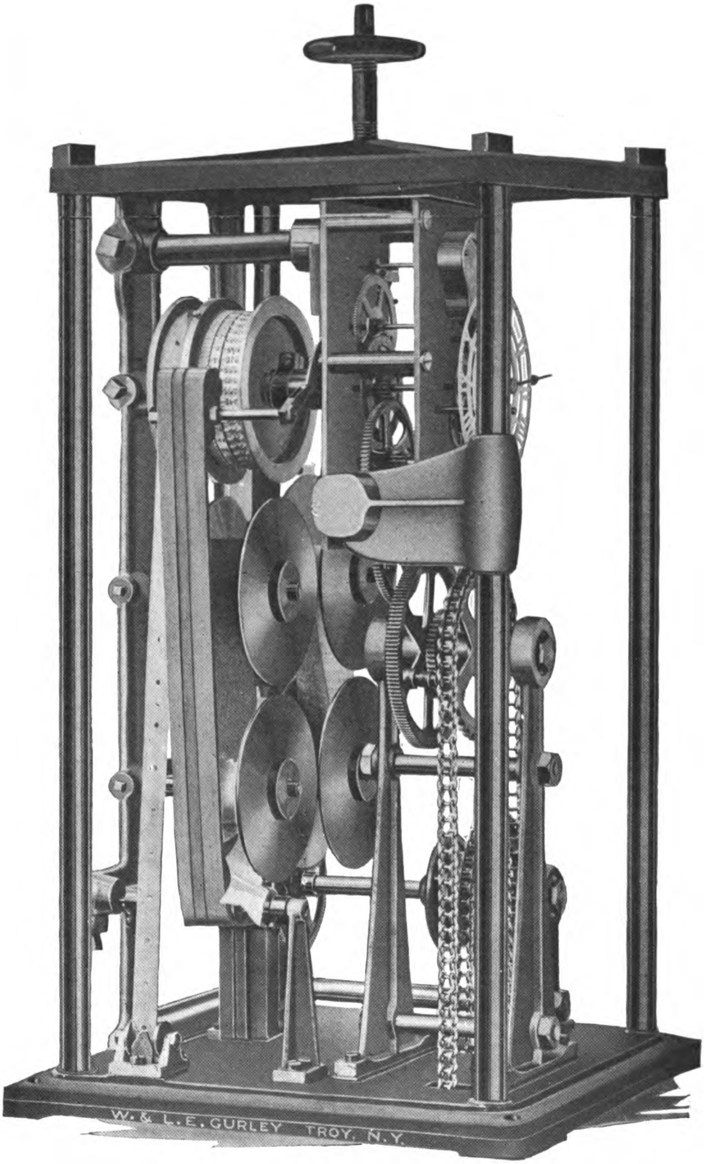

FIG. 45.— No. 630 Printing Water Stage Register.
Side view, showing paper reels, type wheels and cushioned hammer.

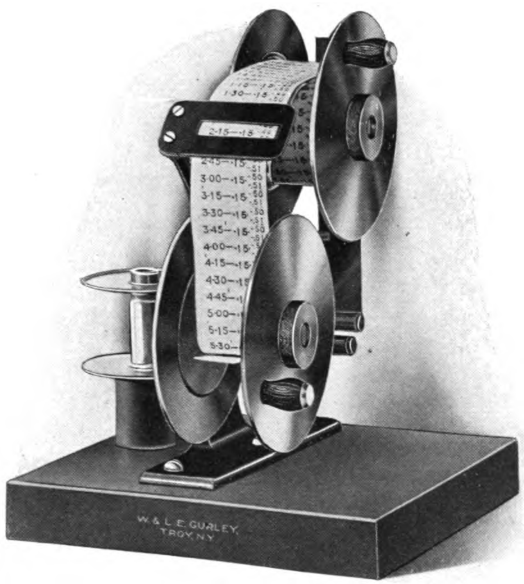

FIG. 46.—No. 632 Tape Reel, for use with
No. 630 Printing Register.

For convenience in handling and examining records on the printed tape, a Tape Reel is provided, as shown above. The tape is wound upon a storage spool, or may be passed from one spool to another over a table, under a thin metal plate through an opening in which the figures on the tape may be observed, and such notations as are desired made upon it while it is wound from one spool to the other.

CONSTRUCTION OF GURLEY PRINTING REGISTERS

A base (1) about 14 inches square, (See Figs. 47, 48 and 49), at either corner of which is a rod (2) 22½ inches long supporting a top (3), forms a frame for the register. On the base (1) extending to top (3) is the back frame (4) which supports the clock, paper reels, sprocket, and type wheels.

The recording mechanism consists of three parallel type wheels, viz.—the time wheel (5), the even foot wheel (6), and the hundredth of foot wheel (7), on the face of which are raised figures and divisions indicating, respectively, the period of time from one to twelve hours, divided into intervals of 15 minutes; the number of feet from 0 to 36; and the hundredths of a foot

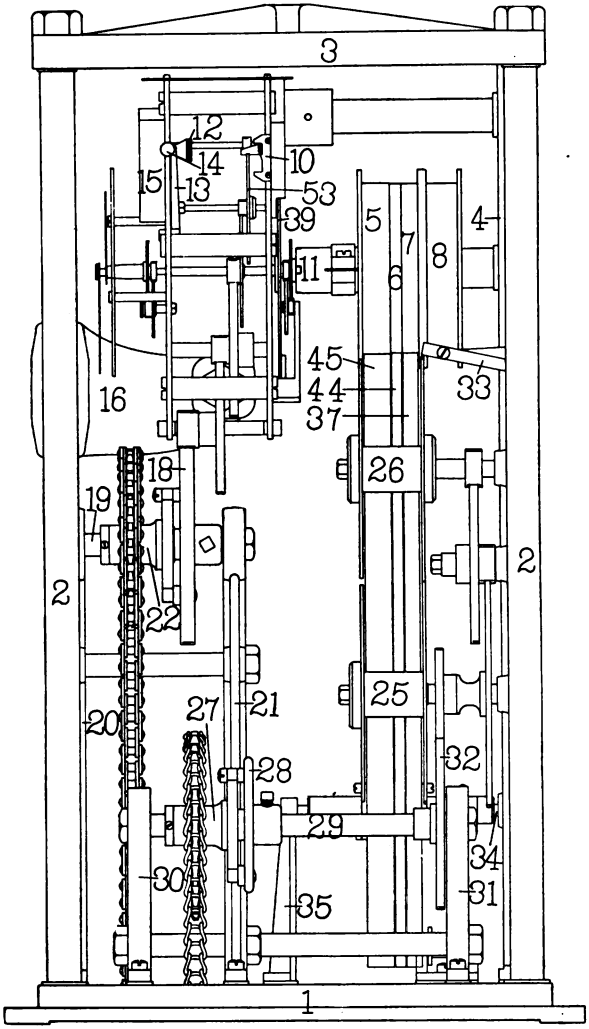

Fig. 47.—No. 630 Printing Water Stage Register.

from 0 to 100. If the water should rise above this height, no trouble will be experienced in determining the stage of the water.

The type wheel indicating time (5) is controlled by a weight driven clock of finest construction, and with full jewelled escapement (9) which is compensated to endure variations of

temperature without variation in its regular operation. The escapement is protected by a dust cover (15) which is transparent. The escapement may be disengaged from the clock train by the use of the nut (12), the spring (13), and the milled head screw (14).

The weight driven clock is very simple in construction, extra heavy, beautifully made, the end of the shaft next to the escapement being hardened and having a sapphire bearing with what is called the "olive hole." This care reduces the retarding effect of the thickening of the oil to a minimum, and is taken so that the mesh of the escapement is always in the same relation with the wheel on the escapement shaft. The escapement is fully jewelled and has a compensating balance wheel. Thus the clock will run uniformly in heat and cold.

When a clock movement is subjected to cold, the hair spring contracts and becomes stronger. The steel rim and center of the balance contracts, as does also the brass rim; but as the brass rim contracts more than the steel rim, it has the effect of straightening the rim—thus increasing the diameter of the wheel, and carrying the mass of its weight further away from the axis, which has a retarding effect.

The clock is rigidly supported by the back frame (4) and the front left hand corner rod (2). It has a thrust brace (16) and an adjusting screw (17). The driving wheel of the clock train (18) is on a shaft (19) which is supported in ball bearings by the two standards (20) and (21). On the shaft (19) is a loose sprocket wheel and a ratchet wheel (22) that drives the clock train with a pawl and spring working on the driving gear wheel. The clock weight hangs on one end of a chain (54) that passes over the sprocket wheel (22).

The clock will run continuously for a length of time depending on the depth of the well, the weight falling 1½ inches in 24 hours. Registers have frequently operated for six months with one winding. The clock weight may be raised whenever required, without moving the cover or in any way interfering with the operation of the register.

Four reels, mounted on the main standard of the instrument, carry and receive the paper strip and the carbon backing. A strip of paper two feet long and 1¼ inches wide is all that is required for the ninety-six impressions made in twenty-four

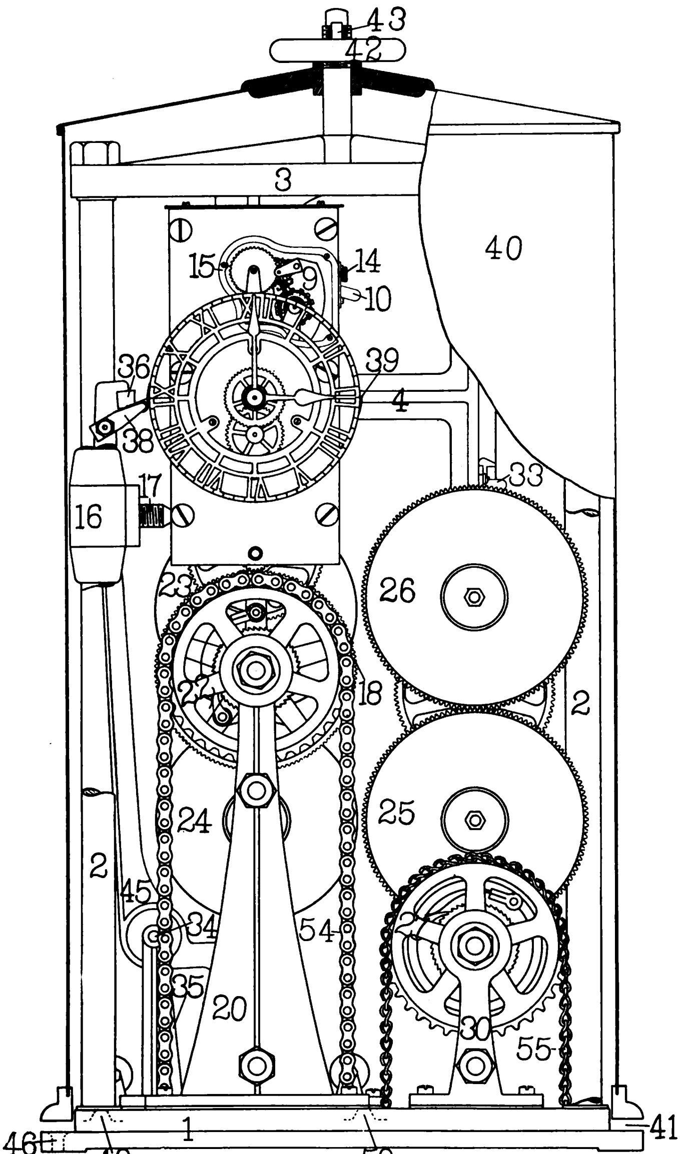

Fig. 48.— No. 630 Printing Water Stage Register.

hours. Moisture has no effect on the record, which is printed directly on the paper.

The carbon paper is supplied from reel(23)and the record paper from reel (24). Both strips pass over the type wheels (5, 6, and 7), the carbon face against the white record paper, and the carbon strip is then received on reel (25) and the printed record paper on reel (26). Both strips are held taut by the tension of a weight (56) (See Fig. 49) attached to a chain (55) that passes over the sprocket wheel (27). This sprocket wheel also has a ratchet wheel attached to it, which is engaged by a pawl and spring working on a flange wheel (28) fastened to a shaft (29) and carried in ball bearings by two standards (30 and 31); fastened to shaft (29) is a gear wheel (32) which is in mesh with a train of gears connecting with the receiving reels (25 and 26). A locking device (33) is provided to lock this train of gears when taking the record off the instrument.

The two type wheels indicating water stage (6 and 7) are moved by a sprocket wheel (8), connected to the float and counterweight (51) by a perforated phosphor bronze band (47), so that any change in the water stage is immediately indicated by a corresponding movement of the type wheels (6 and 7). See Fig. 47.

The hammers, one for the time (45), one for the even foot (44), and one for the hundredth of a foot (37) are pivoted on a shaft (34), one end of which is carried by the back frame (4) and the other by a standard (35). The lower ends of the hammers are weighted and the upper ends have a cushioned face (36). Attached to the side of the hundredth hammer (37) is a roller and holder (38) which travel in a saw tooth cam (39). The number of teeth on the cam, one, two, or four, depends on the time interval desired between successive printings of the record. The cam moves with the clock and pushes the hammers back until the point of the cam passes the holder (38) whereupon the hammers fall, allowing the cushioned face (36) to strike a blow on the record paper and its carbon backing covering the type wheels (5, 6, and 7) thus printing the time and height of water on the paper record. The points of the cam are made of hardened steel, to always insure a sharp edge where the hammer drops from the cam.

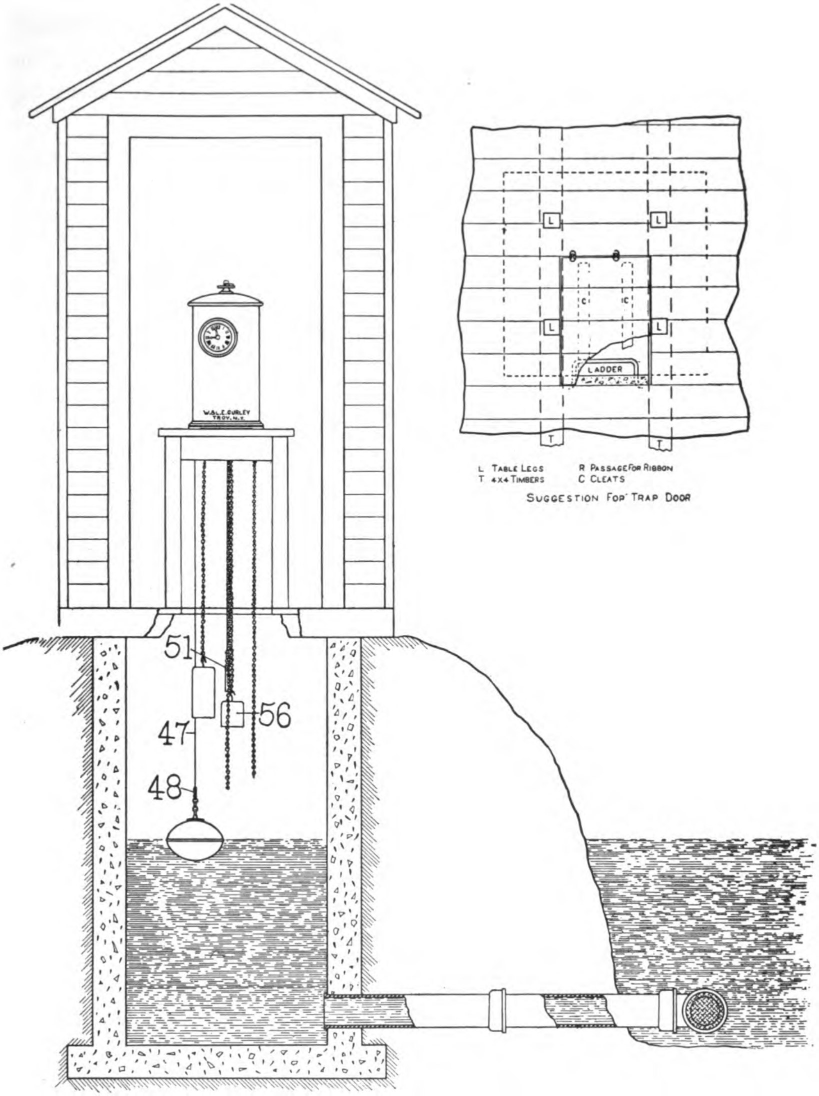

FIG. 49.—Details of Installation of No. 630 Printing Register.

The register as above described, when in use is covered by a metal hood (40) fitting tightly at the bottom on a rubber gasket (41), and having at the top a screw nut (42), which may be secured by a lock through the slot (43) to prevent removal of the case by unauthorized persons. The face of the clock

may be seen through a glass-covered opening in the metal hood, and the clock may be wound from the outside by lifting the weight by one hand and pulling the driving chain with the other at such intervals as required, without the removal of the case or disturbance of the instrument. The paper mechanism may be wound in a similar manner.

The large diameter of the copper float, 10 inches, enables it to respond immediately to any variations in the height of the water, the slightest change being recorded. Its size and shape render it extremely sensitive, and the top is rounded so that foreign matter cannot lodge on it and change the degree of immersion.

The instrument is made of metal throughout and is of the highest grade of mechanical construction, which insures accuracy in operation.

INSTALLATION AND OPERATION OF GURLEY PRINTING REGISTERS

An appropriate shelter* for the register is required at each station. The door and windows of the shelter should be closed while making adjustments, if the wind is blowing.

The box in which the instrument is shipped with the packing material in it should be kept at hand in case it is desired to ship the register to another gaging station at some later time.

Before moving the metal cover of the register, the house should be swept clean. The mechanism of the register, like that of any other high grade clock, should be protected from dust whenever the cover is taken off. The cover, when removed from the gage, should be set down in a clean place, otherwise it will carry dust to the register. The necessary openings through the gage table and floor of the shelter may be located properly by using the template, which is sent with each instrument for that purpose. When the holes have been bored, place the register on the gage table, take off the metal cover (40) and put the four wood screws through the holes (46) into the gage table. Then remove carefully from the parts of the register the packing used to protect the mechanism during shipment.

Find the exact stage of water in the well by reading the hook or other fixed gage. Then revolve the sprocket wheel (8)

*See U. S. Geological Survey, Water Supply Paper No. 371.

until the foot mark on the middle type wheel (6), corresponding to the foot mark on the hook gage, is opposite the center of the hammer. Continue to revolve the sprocket wheel (8) until the hundredth mark on the type wheel (7), corresponding to the hook gage reading, is correctly in line with the center of the foot figure which is always the index.

Attach the perforated band (47) to the clamp (48) on top of the float and let the float down into the well through the trap door in the floor of the shelter, allowing the perforated band to unwind, like thread from a spool, and being careful that it does not kink. Pass the end of the band upward through the slot in the floor and the proper hole in the table and through slot (49) in the base of the register. Bring the band over the sprocket wheel, but do not let the metal band come in contact with the previously adjusted sprocket wheel, and pass it down through the slot (50) in the base of the machine. Through one of the holes in the band put an adjusting pin, so that it will rest across the slot (50) and prevent the metal band pulling over the sprocket wheel. Allow sufficient length of tape below the floor so that the float may freely drop the full depth of the well. Then attach the counterweight (51) to the metal band. Take the pin out of the bronze band, and having the band taut on the float side, lower the counterweight slowly, and carefully fit the perforated band over the spines on the sprocket wheel. Compare the figures on the type wheels (6 and 7) with the exact stage of the water in the well and if they disagree with the water stage reading, having moved a small amount when the perforations of the band were fitted to the spines, this small variation may be corrected and the figures brought to the correct reading by opening clamp (48), thus changing the length of the perforated band. After making this adjustment, tighten the two clamp screws. Before raising the float to make this correction, put an adjusting pin through the tape across the slot in the base on the counterweight side, so that the weight will not drop suddenly. Rapid revolution of the sprocket may damage the mechanism that changes from one foot mark to another on the type wheel, because this mechanism is so constructed that it works extremely fast under normal operating conditions. Once the metal band is adjusted it will hold its adjustment indefinitely.

The clock in the register is shipped with the escapement (9) out of mesh with the clock train. To set the clock to the correct time, turn the large gear (53) between the clock plates, so that the hands will move in a clockwise direction. Do not touch the hands. Loosen the milled head nut (12) on the inside of the front plate of the clock; then turn the milled head screw (14) on the right hand edge of the front plate, until it comes to a stop, but do not force it, and the escapement will then be in mesh with the clock gears. Tighten the milled head nut (12) gently. Next place the chain over the sprocket wheel (22) under the clock, and hang the heavy clock weight on the end of chain (54) on the left side of the sprocket wheel. When hanging the weight on the chain, lower the weight gently in order not to damage the winding mechanism. When winding the clock, use the left hand to raise the weight, and the right hand to pull down the right hand end of the clock chain.

A locking device (10) on the back frame of the clock is used to keep the weight from falling when the escapement is thrown out of mesh with the clock train. In locking the clock train do not force the lever on the tops of the gear teeth, or the bearing on the gear shaft may be damaged. *Before throwing the escapement out of mesh, always lock the clock train if the weight is on the clock.* The escapement would be badly damaged should the gear run at high speed just as it was leaving the teeth on the pinion of the escapement.

When adjusting the clock, with the escapement out of mesh and the weight on the chain, hold the upper large gear (53) of the clock with the left hand and unlock the train with the right; then allow the clock train to revolve until the hands indicate the correct time. Use the left hand as a brake and almost stop the clock just before the high part of the cam reaches the roller on the hammer, and immediately after it passes. This method must be followed exactly, or else the small roller will strike the cam, be damaged, and forced out of adjustment.

Registers are shipped from the factory with the white record paper and the carbon paper in place and properly threaded around the type wheels. The weights on the paper winding mechanism should be hung in the same careful manner as the clock weights. To wind the paper mechanism, use the

left hand to raise the weight and the right to pull down the right hand end of the paper chain.

The locking device on the back frame of the register should be used whenever the paper is being put on or taken off the instrument. If the gear train is not locked before taking off the paper the weight will drop into the well.

When the record is changed, about a foot of white paper should be left beyond the last printed record for facility of handling in the office, as well as for notes made at the time of removal to show the time and hook gage reading. Both the white and the carbon papers should be removed when changing the record.

To change the record, lock the gear train and remove the large round nuts on reels (25 and 26), and then remove the side plates of the receiving spools. This may be done by turning the large round nuts to the left, being careful not to let them drop when they are completely unscrewed from the reel hub. Do not remove the small hexagonal nuts on the reels (25 and 26) from the end of the shaft while the paper weight is on the chain, because the gears of the train might become disengaged and thereupon the weight would drop.

After taking both spools of paper from the receiving rolls (25 and 26), press the paper tubes onto the reel pins and bring the strip of carbon paper over the type wheels and around the under side of spool (25). Attach it to the circumference of the paper tube by means of a short piece of gummed paper, leaving enough carbon paper to make two or three turns around the paper spool. Release the locking device (33), whereupon the mechanism will take up the slack in the carbon paper which will sustain the weight (56). Place the white paper over the type wheels and over the upper right hand receiving spool (26), being sure that the pins on the time type wheels perforate the white paper also. Press a paper tube on the pins of this reel and fasten the end of the white paper to the circumference of the paper spool with gummed paper, having the white paper taut. Take care to see that both strips of paper have the same tension between the type wheels and the receiving reels, and that both strips of paper are close to the flange of the time type wheel. Replace the side plates on the receiving reels and put on the round nuts.

It will be necessary to oil and clean the bearings on the instrument only once a year, with the exception of the two lower bearings on the clock plates and the small roller on the hammer; and these should have a drop of oil once in three months. To oil the instrument, use only the best watch oil that is sent with it, and which will prevent the instrument from sticking in extreme cold weather. The oil should be applied carefully to the bearings, using a wire for that purpose. Never apply oil to the teeth of any of the clock gears except (18) which may be oiled with a good oil.

The lower bearings in the clock frame are covered with small caps having oil holes on the upper side. The bearings above have no oil holes or caps, so that the drop of oil should be put on the shaft next to the bearings. The internal mechanism of the type wheels should be oiled once a year, but it is not necessary to take the type wheels apart to clean or oil them. When oiling the type wheel gears, remove the white and carbon papers from them and place a cloth under the wheels to catch any surplus oil that may run down between them. Also take the perforated phosphor bronze band off the sprocket wheel so that it will be possible to turn the sprocket wheel until the center type wheel has made at least one complete revolution in each direction, during which time the sprocket wheel will have made seventy-two revolutions. In passing from one foot mark to another turn the sprocket wheel slowly. Before taking the metal band off the sprocket wheel put a mark with a soft pencil on both band and sprocket wheel flange so that the band may be put back quickly into the same position. Raise the counterweight (51) about 6 inches and put a pin through the same perforated band at the base of the instrument to support the weight and use a piece of cord tied to the top of the register to loop up the tape so that it will not be damaged during the operation.

The small screw in the center of the shaft that supports the sprocket and type wheels should be removed and in its place should be screwed the small pump furnished for that purpose, filled with oil. The oil should be forced in as quickly as possible and the operation repeated two or three times until the oil runs out between the type wheels.

Gurley Graphic Water Stage Registers

Normal Vertical Range, 0 to 10 feet
Time Scale, 7 days, 4 days, or 1 day

Patented Aug. 4, 1914.

Fig. 50 on page 103 illustrates an improved Graphic Register having several unique and valuable features. It is of simple construction, with few parts; is designed for easy operation, and adapted for a wide range of conditions. Its construction is such that no lost motion will develop from continuous service and it can be operated with minimum care and expense.

The following vertical scales can be furnished:

0 to 1 foot,	0 to 5 feet,	0 to 15 feet,
0 to 1½ feet,	0 to 6 feet,	0 to 20 feet,
0 to 2 feet,	0 to 8 feet,	0 to 1½ meters,
0 to 3 feet,	0 to 10 feet,	0 to 3 meters.
0 to 4 feet,	0 to 12 feet,	

A time scale of 1 day, 4 days, or 7 days can be furnished. As the record of stage is made around the cylinder, there is no limit to the number of revolutions possible and, hence, to the range of stage. Therefore, it is advisable to use as low a range as possible and hence a more accurate reading of the water stage. If occasionally the water stage is above the range of the register, no trouble will be experienced in reading the water level.

ADVANTAGES OF GURLEY GRAPHIC REGISTERS

Constancy of performance. These registers have been brought to their present high state of excellence through years of experiment. They have been developed to meet actual field conditions and are performing with satisfaction under a great variety of physical conditions in all parts of the world. Once properly installed they require a minimum of attention.

Low cost. From the standpoint of maintenance and operation Gurley Water Stage Registers represent the smallest possible permanent investment. First cost is also reduced to a minimum in these registers.

Mechanical excellence. Every part is made of properly selected material finely finished to insure accuracy of opera-

tion. The superior mechanical execution is accomplished by expert workmen in a factory that has been producing precision instruments for the past seventy-three years.

Reliability of the time parts. Only properly adapted clocks are used in Gurley registers. They have properly proportioned springs and the escapement has jewelled bearings to insure uniformity of rate. The time screws that drive the pencil carriage are machined with great accuracy, thus insuring a uniform movement of the pencil over the record sheet.

Unlimited range of stage. The record of stage is made around the cylinder,—the time record along its axis—and the cylinder revolves as the stage changes. There is no limit to the number of revolutions possible and hence to the range of stage, while at the same time the movement of the pencil is always in one direction, which assists materially in interpreting the record.

Portability. The light weight of these registers renders them easily portable and hence adapts them to those special hydraulic investigations during which it is necessary to make frequent changes in the position of the register.

Type of record. The hydrograph or curve recording the stage and time is continuous over seven days and presents graphically all of the fluctuations of stage and their time relations. These are shown at a glance by the curve, which is a picture record of conditions. This type of record has many advantages and is especially useful in many situations.

Simplicity of the record. The graphic record is easily interpreted and where desired, may be quickly reduced to statistical form.

Precision and convenience in changing record sheets. The record sheets are cut to fit the cylinder closely and the pencil carriage is adjustable, thus insuring an accurate setting of the time. The cylinder is securely locked in place while changing the record sheet.

The permanence of the setting of the register to the bench mark. The slot which extends through the entire length of the recording cylinder and the two guards that prevent the perforated phosphor bronze band from accidentally slipping over the spines on the sprocket wheel when the record is being taken off, prevent any change or mistake being made by the

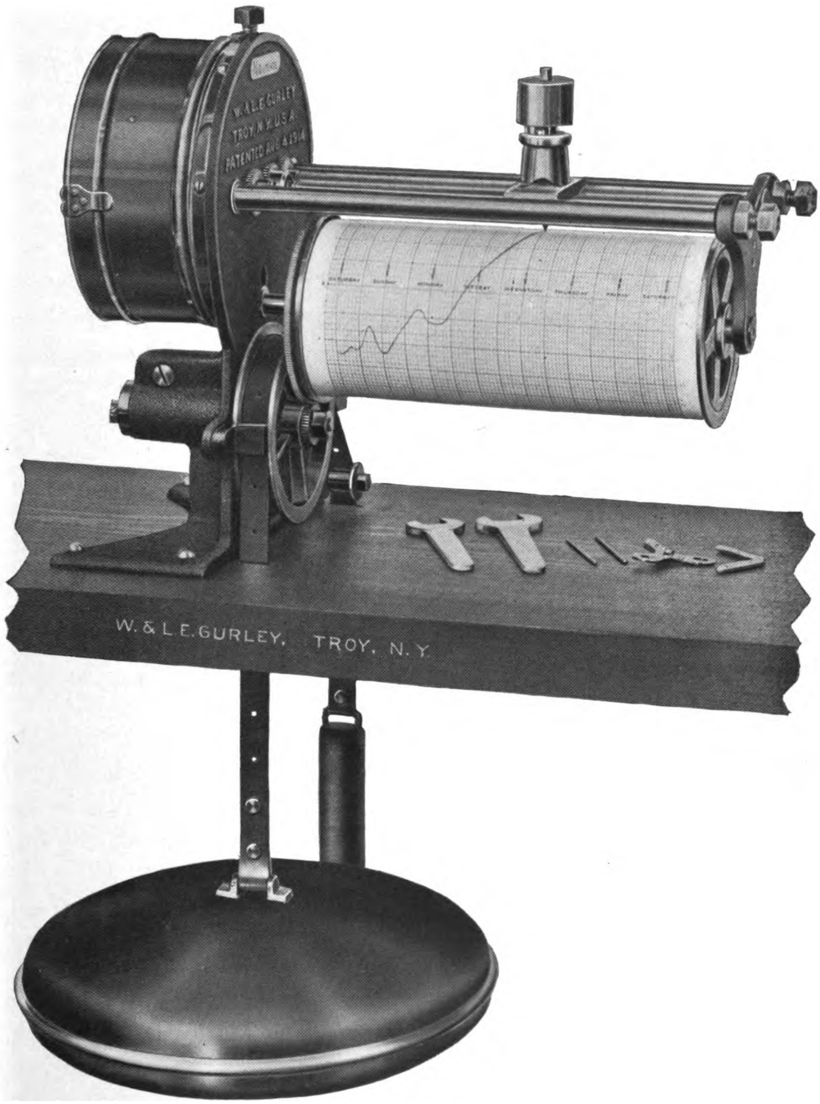

FIG. 50.— No. 633 Gurley Graphic Water Stage Register, with *Spring-driven Clock.*
Normal Range, 0 to 10 feet. Time Scale, 7 days.
For modifications in vertical range and time scale, see page 101.
(See Record Sheet illustrated on page 116.)

observer while handling the register, after it has been properly installed by the engineer in charge.

Changing the range of the register. Simplicity in changing two gears to alter the range of the register.

Size of sheets. The record sheets are adapted to convenient filing in standard filing equipment.

CONSTRUCTION OF NO. 633 GRAPHIC REGISTER

(*The part numbers refer to Fig. 51.*)

The base (1) supports the mechanism of the register. An extra heavy eight-day clock (2) is geared to two time screws (3), which are supported at each end as shown. The clock has two large driving springs and has jewelled bearings on the escapement shaft. Mounted on the two screws is the pencil carriage (4) which moves forward without lost motion, in accord with the turning of the clock shaft, and which can be lifted up from one position on the screws and placed in another, if desired. The pencil (11) is held in the pencil holder (5), which is free to move vertically in a cylinder (6) projecting from the upper side of the base of the carriage (4). The pencil holder (5) is set and the pencil clamped with a screw (25), so that the weight of the pencil and holder presses down against the paper.

The record cylinder (8), on which the paper is placed, is supported at each end as shown. The sprocket wheel (7) is attached to the sprocket wheel shaft (26), and revolves in an eccentric bushing (24). The gear (20) is clamped to the sprocket wheel shaft by the nut (15). The gear (21) is clamped to the cylinder (8) by three small screws. Two guards (9 and 10) prevent the band from slipping over the spines on the sprocket wheel. The bolt (13) is used to lock the cylinder, while changing the record sheet. Extending across the face of the record cylinder (8) is a slot (12), which indicates the point of zero gage height on the record cylinder. Idler pulley (17) is used to spread the metal band so that the counterweight will pass the float. There is a gear (19) on the center clock shaft. The capstan head screw (18) is used for clamping the gear (19) to the clock shaft. Three nuts (22) serve to hold the cover on the register. Clamp screw (23) is to clamp the bushing in the base (1).

In the standard register of this type the pencil travels along the cylinder in seven days time (one inch for each day). It is possible, however, to substitute other screws (3) of such a lead that the pencil will move across the cylinder in four days (two inches for each day), or screws that will move the pencil across the cylinder in one day (eight inches per day). Such an arrangement would be very desirable in situations where there are sudden fluctuations in stage.

A float 10 inches in diameter and $3\frac{1}{2}$ inches thick is used. The whole instrument is enclosed in a sheet metal cover (14), 15 inches long, $8\frac{1}{4}$ inches wide and $11\frac{1}{4}$ inches high, which makes it waterproof and dustproof.

Weight-driven Graphic Register No. 636, shown in Fig. 52, is similar to Register No. 633, with the exception of the clock,

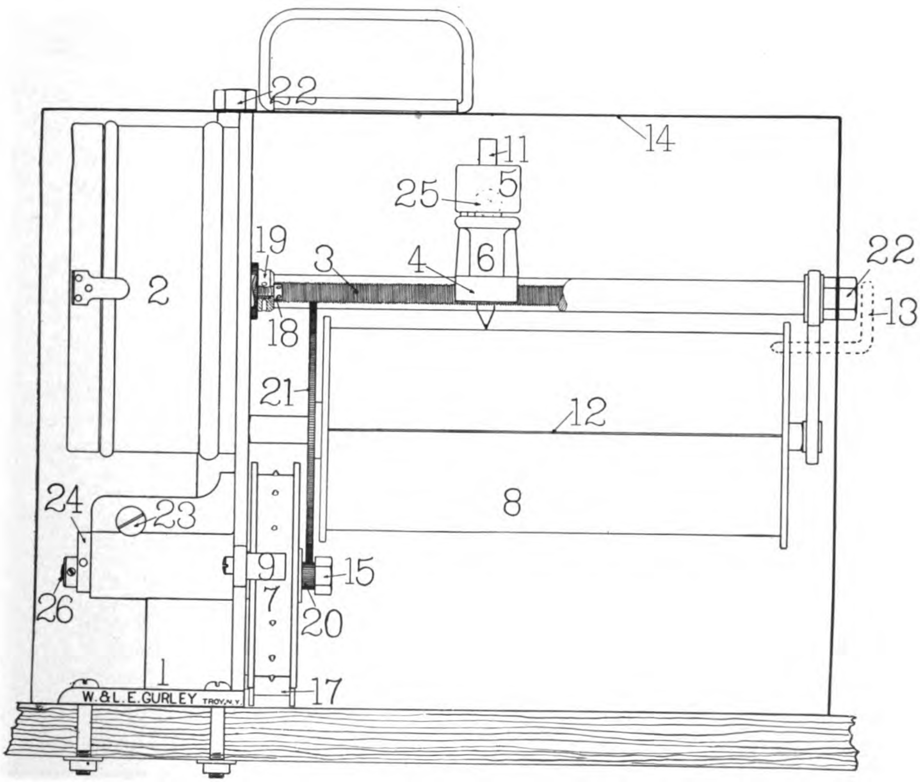

FIG. 51.— No. 633 Gurley Graphic Register.

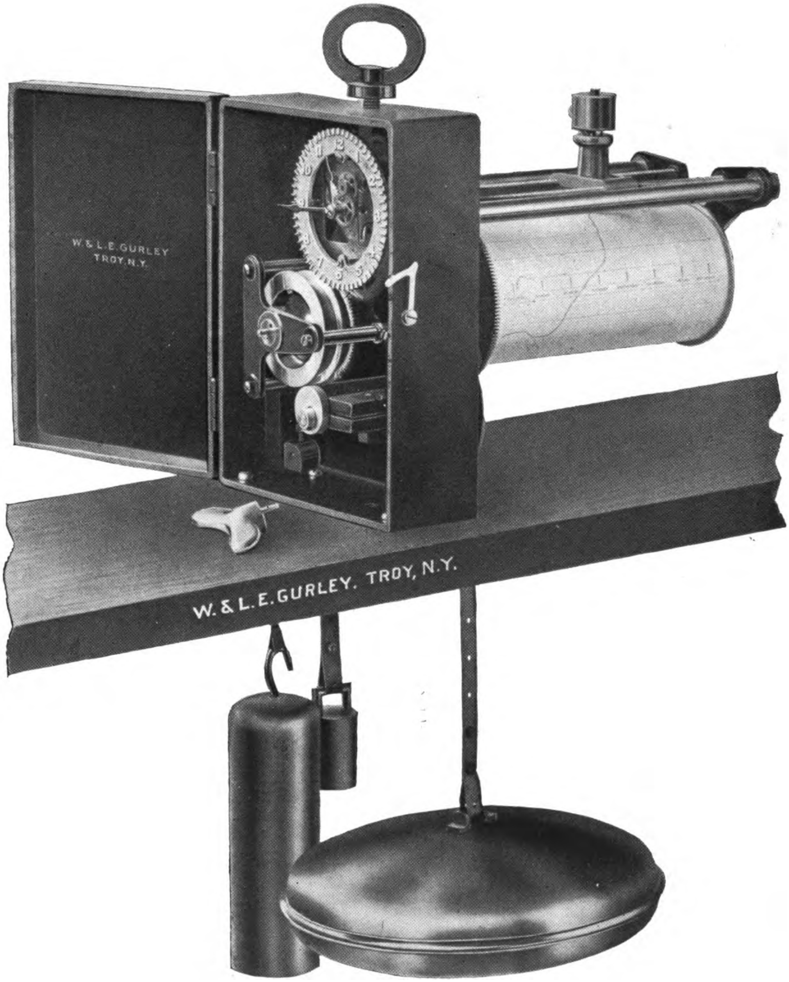

FIG. 52.— No. 636 Gurley Graphic Water Stage Register, with *Weight-driven Clock.*
Normal Range, 0 to 10 feet. Time Scale, 7 days.
For modifications in vertical range and time scale, see page 101.
(See Record Sheet illustrated on page 116.)

which is weight-driven, the weights falling at the rate of 10 inches per day. If this register is set high enough above the water, the pencil can be made to travel across the paper in two weeks, or at the rate of ½ inch per day.

INSTALLATION AND OPERATION OF GURLEY GRAPHIC REGISTERS NOS. 633 AND 636

A large element in the satisfactory operation of an automatic register is proper installation. The results from the best register will be impaired by improper installation, whereas a register properly installed will give a record the accuracy of which depends solely on the adequacy of the instrument. The value of approximate results is not commensurate with the expense of an automatic register; therefore, the method of installation should be so thorough as to insure accuracy.

In installing an automatic register, it is necessary to provide a well for the float, connected with the water to be measured by an intake pipe. If necessary, a valve should be used in the well on the intake pipe, so that the water can be throttled to prevent any surge appearing on the record sheet.

To place the register permanently. The register is usually placed on a table having holes cut for the phosphor bronze band. Place the register in its proper position and fasten it to the table by the quarter-inch bolts that are furnished. Attach the metal band to the float; lower the float to the surface of the water; bring the metal band up through the table and over the sprocket wheel; then down through the table and attach the counterweight.

To place the pencil carriage on the screws. The pencil carriage is engraved, "Toward clock". It is important to place the carriage on the screws in the correct position. To do this, tip the carriage so that one side will fit on the screw, then swing down as on a hinge until it rests on the other screw.

To set the pencil to the exact height. Insert the record sheet in the ¾ inch deep slot which extends through the entire length of the recording cylinder. This will hold the paper securely and always bring the sheets in the same position on the cylinder. Loosen nut (15). The pencil point being the index, hold the sprocket wheel so it cannot move. Turning the recording cylinder until the pencil indicates on the paper the correct height of the water, clamp the gear (20) to the sprocket wheel (7) with the nut (15).

To set the pencil to the exact time, loosen the capstan head screw (18), revolve the screws (3) by turning gear (19) with

an adjusting pin, until the pencil point indicates the exact time; hold the gear (19) with an adjusting pin, and clamp the gear (19) to the clock shaft with the screw (18).

To change the record sheet, raise the float by turning the record cylinder (8) and lock it by the bolt (13), thus bringing the slot (12) in the most convenient position. Cut the adhesive paper on the margin of the record sheet. With finger on the inside of the cylinder (8), push out the ends of the record sheet, which can readily be taken off from the outside of the cylinder. Insert the corner of the new sheet that indicates the

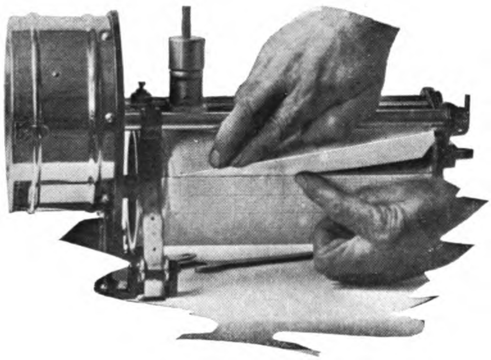

FIG. 53.— Showing method of inserting ends of the Record Sheet in the Slot in the Cylinder.

highest gage height; gradually press it into the slot until the upper end of the sheet is in the slot; bring the paper around the cylinder and insert the corner of the sheet marked 0, pressing it in without kinking the paper until that end is in slot (12). (See Fig. 53). Stick a small piece of adhesive paper on the margin and over the slot. When folding the edge of the record sheets, be careful to keep the folded edge straight or trouble will be experienced in inserting the record sheet in the slot in the cylinder.

Care of the record sheets. It will facilitate putting record sheets on the cylinder if after folding the edge, about twelve record sheets are put in a 2-inch paper tube with rulings toward the outside. Roll and put one sheet in at a time, so when one is to be put on the register, it will not be necessary to take all of the sheets out of the tube. Keep the sheets in a

dry place, so that the paper will be hard while inserting the record sheet in the cylinder. If it is desirable to keep the record sheets in the gage house, the paper tube with the record sheets should be kept in a two-quart fruit jar, and when taking record sheets out, open and close the jar as quickly as possible. If the atmosphere is damp when filling the jar with record sheets, place the jar with the sheets in a hot place and when heated thoroughly, put a rubber ring on the jar and screw on the cover.

To oil the register. The clock will run two years with one oiling; however, if it stands idle for one month, it will be necesssary to take off the hands and face and oil it with the best clock oil. The bearings of the screws and of the cylinder should be oiled with the above mentioned oil about four times a year. A very small amount of oil should be used on the screws every month. A fine wire should be used in applying the oil.

Gurley Graphic Water Stage Registers

Normal Vertical Range, 0 to 1 foot — Natural Scale.

Time Scale, 7 Days, 4 Days, or 1 Day.

Patented August 4, 1914.

This register may be used as a natural scale graphic register of great accuracy for a normal range of one foot. Multiples thereof are recorded as complete revolutions of the cylinder.

The float furnished with the register is 10 inches in diameter. The power of the weight of a column of water 10 inches in diameter and 1/100 of a foot high is 5.47 ounces. Thus this float gives great lifting power and corresponding accuracy.

The natural scale register is designed to meet those requirements which demand a full size record of stage. As usually constructed the time scale is 1 inch per day, but it is possible to arrange special screws to other scales. This register is especially adapted to the measurement of the flow of any liquid over weirs. It will give the height of liquid on the weir with great precision. For this purpose it is easily applied to

(1) Sewage disposal works,
(2) Sanitary sewers,
(3) Irrigation works,
(4) Venturi flumes.

It is equally well adapted to use

(5) In stream gaging,
(6) On power canals,
(7) On irrigation canals,
(8) On navigation canals,
(9) On drainage canals,
(10) In reservoirs of all kinds,
(11) In measuring flow from pumps, wells, etc.
(12) As a portable gage for use in special studies and investigations.

Its construction is such that no lost motion will develop from continuous service and it can be operated with minimum care and expense. This instrument is a perfect weir gage and

FIG. 54.— No. 634 Gurley Graphic Water Stage Register.
Normal Range, 0 to 1 foot — Natural Scale. Time Scale, 7 days.
(See Record Sheet illustrated on page 117.)

If this register is equipped with a sprocket wheel 2 feet in circumference, instead of 1 foot, as on Register No. 634, the range of the instrument is from 0 to 2 feet, and it is known as Register No. 634-A.

has no equal in simplicity of construction, accuracy, ease of operation, and durability.

These Gurley registers are being used extensively by different Departments of the United States Government; also by many municipalities in connection with their sewer systems and sewage disposal plants.

ADVANTAGES OF GURLEY GRAPHIC REGISTERS

The advantages of Registers Nos. 634 and 634-A are the same as those given under Registers Nos. 633 and 636, on pages 101, 102 and 104.

CONSTRUCTION OF NO. 634 GRAPHIC REGISTER

(The part numbers refer to Fig. 55)

The base (1) supports the mechanism of the register. An extra heavy eight-day clock (2) is geared to two time screws (3) supported at each end, as shown. The clock has two large driving springs and has jewelled bearings on the escapement shaft. Mounted on the two screws is the pencil carriage (6) which moves forward without lost motion, in accord with the turning of the clock shaft, and which can be lifted up from one position on the screws and placed in another, if desired. The pencil (11) is held in a pencil holder (5) which is free to move vertically in a cylinder projecting from the upper side of the base of the carriage (4). The pencil holder (5) is set and clamped with a screw, so that the weight of the pencil and the holder presses down against the paper. The recording cylinder (8), on which the paper is placed, is supported at each end, as shown. The sprocket wheel (7) is movable on the cylinder axis and is clamped to the cylinder (8) by the nut (15). Two guards (9 and 10) prevent the band from slipping over the spines on the sprocket wheel, and bolt (13) is used to lock the cylinder, while changing the record sheet. Extending across the face of the recording cylinder (8) is a slot (12), which indicates the point of zero gage height on the record cylinder.

In the standard register of this type the pencil travels along the cylinder in seven days time. It is possible, however, to substitute other screws (3) of such a lead that the pencil will move across the cylinder in either four days, or

twenty-four hours. Such an arrangement would be very desirable in situations where there are sudden fluctuations in stage.

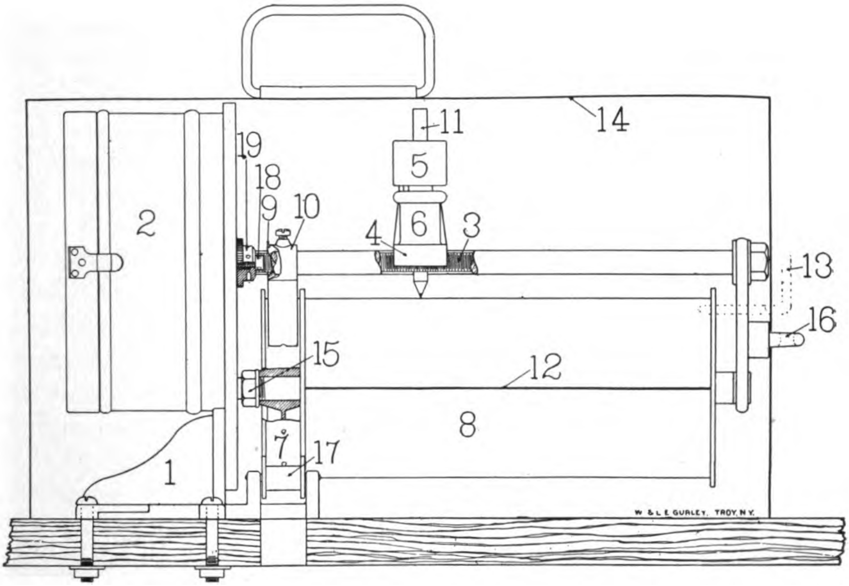

Fig. 55.— No. 634 Gurley Graphic Register.

Idler pulleys (17) are to be used when it is necessary to allow the counterweight to pass the float. On the center clock shaft is a gear (19), which is clamped on the shaft by capstan head screw (18).

A float 10 inches in diameter and 3½ inches thick, is used. The whole instrument is enclosed in a sheet metal cover (14), 15¾ inches long, 7½ inches wide, and 9 inches high, which makes it water-proof and dust-proof. The extension (16) is for locking the cover on the register.

INSTALLATION AND OPERATION OF GURLEY GRAPHIC REGISTERS NOS. 634 AND 634-A

A large element in the satisfactory operation of an automatic register is proper installation. The results from the best register will be impaired by improper installation, whereas a register properly installed will give a record the accuracy of

which depends solely on the adequacy of the instrument. The value of approximate results is not commensurate with the expense of an automatic register; therefore, the method of installation should be so thorough as to insure accuracy.

In installing an automatic register, it is necessary to provide a well for the float, connected with the water to be measured by an intake pipe. If necessary, a valve should be used in the well on the intake pipe, so that the water can be throttled to prevent any surge appearing on the record sheet.

To place the register permanently. The register is usually placed on a table having holes cut out for the phosphor bronze band. Place the register in its proper position and fasten it to the table by the quarter-inch bolts that are furnished. Attach the metal band to the float; lower the float to the surface of the water; bring the metal band up through the table and over the sprocket wheel; then down through the table and attach the counterweight. If the register is set high enough, it is unnecessary to pass the metal band over the pulleys (17).

To place the pencil carriage on the screws. The pencil carriage is engraved, "Toward clock." It is important to place the carriage on the screws in the correct position. To do this, tip the carriage so that one side will fit on the screw, then swing down as on a hinge until it rests on the other screw.

To set the pencil to the exact height. Insert the record sheet in the ¾ inch deep slot which extends through the entire length of the recording cylinder. This will hold the paper securely and always bring the sheets in the same position on the cylinder. Loosen the nut (15). The pencil point being the index, hold the sprocket wheel so it cannot move; turn the recording cylinder until the pencil indicates on the paper the correct height of the water; and clamp the sprocket wheel (7) to the cylinder (8) with the nut (15).

To set the pencil to the exact time, loosen the capstan head screw (18), revolve the screws (3) by turning gear (19) with an adjusting pin until the pencil point indicates the exact time; hold the gear (19) with an adjusting pin, and clamp the gear (19) to the clock shaft with the screw (18).

To change the record sheet, raise the float by turning the record cylinder (8) and lock it by the bolt (13), thus bringing

the slot (12) in the most convenient position. Cut the adhesive paper on the margin of the record sheet. With finger on the inside of the cylinder (8), push out the ends of the record sheet, which can readily be taken off from the outside of the cylinder. Insert the corner of the new sheet marked 1.00; gradually press it into the slot until the upper end of the sheet is in the slot; bring the paper around the cylinder and insert the corner of the sheet marked 0, pressing it in without kinking the paper until the end is in slot (12). (See Fig. 53, page 108). Stick a small piece of adhesive paper on the margin and over the slot. When folding the edge of the record sheets, be careful to keep the folded edge straight, or trouble will be experienced in inserting the record sheet in the slot in the cylinder.

Care of the record sheets. It will facilitate putting record sheets on the cylinder if after folding the edges, about twelve record sheets are put in a 2-inch paper tube with rulings toward the outside. Roll and put one sheet in at a time, so when one is to be put on the register, it will not be necessary to take all of the sheets out of the tube. Keep the sheets in a dry place, so that the paper will be hard while inserting the record sheet in the cylinder. If it is desirable to keep the record sheets in the gage house, the paper tube with the record sheets should be kept in a two-quart fruit jar, and when taking record sheets out, open and close the jar as quickly as possible. If the atmosphere is damp when filling the jar with record sheets, place the jar with the sheets in a hot place and when heated thoroughly, put a rubber ring on the jar and screw on the cover.

To oil the register. The clock will run two years with one oiling; however, if it stands idle for one month, it will be necessary to take off the hands and face and oil it with the best clock oil. The bearings of the screws and of the cylinder should be oiled with the above mentioned oil about four times a year. A very small amount of oil should be used on the screws every month. A fine wire should be used in applying the oil.

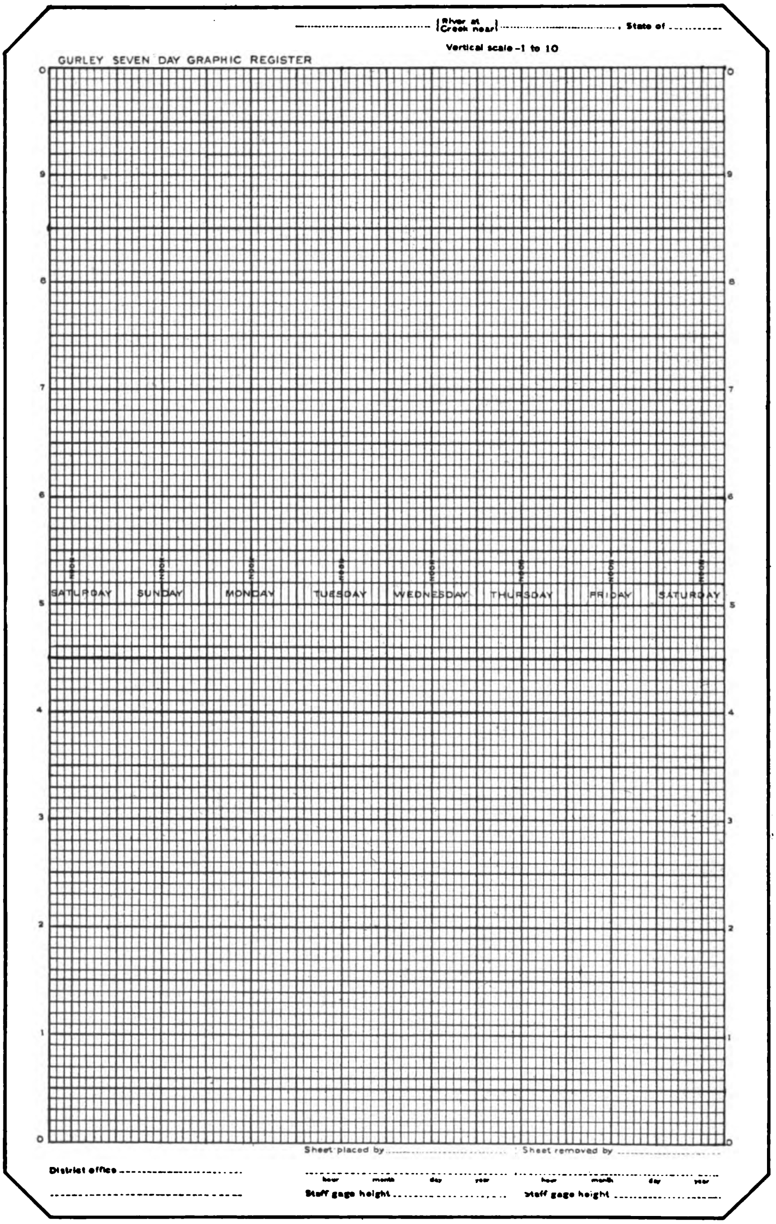

FIG. 56.—Record Sheet for No. 633 or No. 636 Graphic Register. Normal range, 0 to 10 feet. Time scale, 7 days. See pages 103 and 106.

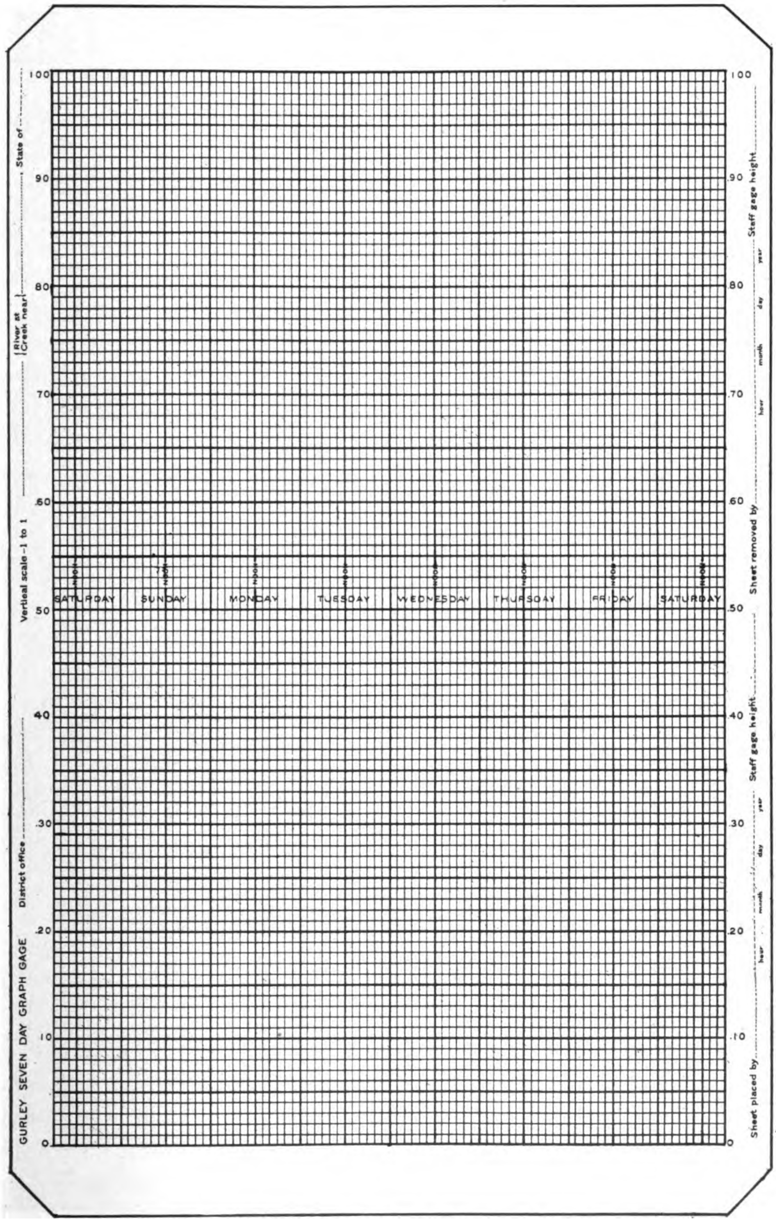

FIG. 57.— Record Sheet for No. 634 Graphic Register.
Normal range, 0 to 1 foot — Natural Scale. Time Scale, 7 days.
See page 111.

INSTALLATION AND SHELTER OF WATER STAGE REGISTERS

When an automatic register is used continuously it is necessary to provide (1) a well for the float and an intake pipe to connect the well with the river, (2) a house to shelter the register, and (3) staff or hook gages referred to permanent bench marks for use in checking the record and maintaining the datum. (See Figs. 40 and 41). For temporary use as in special studies, a portable shelter, Figure 58, may be used.

FIG. 58.— Portable Shelter installed by U. S. Geological Survey on Kinderhook Creek at Rossman, N. Y. The insert shows the outfit, including a Gurley Graphic Register, packed ready to carry.

Proper installation is so large an element in the satisfactory operation of an automatic water stage register that much care should be taken when installing the equipment. Results from the best of registers will be impaired by improper installation, whereas a register properly installed will give a record whose accuracy depends solely on the refinement of the instrument. Much care in installation is, therefore, essential; and,

if the register is to record stream heights during Winter months and during flood stages, the installation must be protected from cold and from floating ice, logs, debris, etc.

In the ideal structure, illustrated in Fig. 25, the well and the house should be located far enough back from the river to be out of danger from floating ice or drift, and to provide sufficient protection for the well and pipes to prevent freezing. A permanent ladder should extend to the bottom of the well, so that the float and intake pipe can be readily inspected. If the installation is to be maintained for a long period the well should be lined with concrete, otherwise a heavy plank lining may be used. The intake pipe should be placed well below the lowest stage of the river and provided with a screen for keeping out fish and foreign material. It should also be provided with a gate valve where it enters the well, so that the flow can be reduced if necessary, to eliminate wave action, or entirely shut off for purposes of inspection or for repairs.

Two non-recording gages, referred to permanent bench marks, should be installed with each automatic register, in order to check the readings of the automatic register with the stage of the river. One, of the type best suited to the locality, should be placed in the river and the other, preferably a hook gage, should be located in the float well to aid in setting and checking the recording register, and, by comparison with the river gage, to indicate any interruption in the free communication with the river. The river gage should be in the same cross-section of the river, as the intake pipe, care being taken to have it rest on a solid foundation. It may, however, be dispensed with by using a reference point so located that the elevation of the water surface can be readily determined.

The well is essentially a stilling box for the float. It must be large enough to accommodate the float, driving and counter weights, and the hook or staff gage, from extreme low to extreme high water, and to permit them to be inspected readily. Experience shows that if the well is more than 8 feet deep these conditions are met best by a well 2½ by 5 feet in cross-section. For wells up to sixteen feet in depth this cross-section will give, in the long run, greater satisfaction than a smaller one, while even for deeper wells, if in easily excavated material,

it may cost no more. When for good reason high priced materials of construction are used, the reduction of the dimensions of the cross-section to 3 by 4 feet may be advantageous, especially if it is possible to provide several entrances to the well between high and low water.

The materials of construction suitable for lining wells include timber (usually treated with a wood preservative), brick, vitrified tile pipe, concrete, plain or reinforced in mass, concrete rings, stone, cast iron pipe, riveted steel pipe, and galvanized wrought iron culvert pipe.

On the degree of certainty with which the useful life of the station may be predicted will depend the general choice of the material to use at any given station, longer usefulness requiring more durable material. The specific choice will depend on the accessibility of the station and on the availability of labor and material.

In northern latitudes attention must be given to the possibility of the water in the well freezing, with the consequent interruption of the record, but in a well properly constructed and placed far enough back from the river there should be no danger from frost, even in temperature as low as 30 degrees below zero. Several methods are available, the choice among them being made on the basis of first cost versus cost of operation. Where the first method is used,—that of higher first cost,—the well is placed far enough back in the bank to be protected against cold. To obtain this protection the well should be built so that the water surface during the Winter season is at least two feet below the depth of maximum frost. Guarding against the possibility of freezing allows more freedom in the choice of observers.

Where such construction does not seem advisable an oil cover may be applied, using a depth of oil equal to the maximum thickness of ice, plus 2 feet. A device for reducing the quantity of oil required is shown in Fig. 59. In some cases the device of building a jacket around an exposed well has been resorted to. Between the well and the jacket a space of 2 feet is left, which is filled with manure, leaves, or some similar material. The jacket is carried up 8 feet above the water surface.

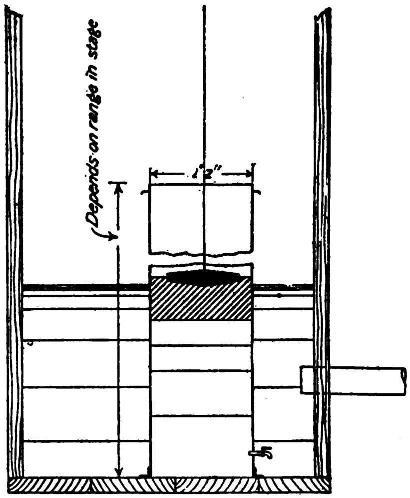

Fig. 59.— Device for reducing quantity of oil used as a cover in wells.

If near a suitable electric circuit, an electric heater can be used in the end of a ¾ inch galvanized pipe, the heated end resting on the bottom of the well and the pipe being long enough to extend through the floor of the register house. The heater should be used only in extremely cold weather. A rheostat that could be attached to the under side of a float and which would turn on the current when the water was 34 degrees Fahrenheit would be desirable for economy. If the water in the well is over heated, everything in the register house will be covered with a heavy coating of frost and thus interfere with the working of the register.

The type of house to be used at any station is selected after consideration has been given to the three elements,— utility, safety, and appearance. If a station is to be operated all year round the house must be large enough to allow the observer to go inside during inclement weather and to pass conveniently around the register table while inspecting or adjusting the register. Plenty of light in the shelter is very desirable when setting the gage height, changing the record, or otherwise adjusting the register. For a permanent field installation a concrete well and shelter, which will also afford fire protection, (Figs. 60 and 61), are recommended as a matter of economy.

Portable wooden* or sheet metal houses**, 5 by 6 feet in plan, have been used with success in appropriate locations. The cost of such shelters is small, and they may be obtained quickly from stock from their manufacturers. In arid regions, if the station is to be operated only during warm weather and where rain is not likely to interfere with the inspection and adjustment of the register, simpler types of shelters may be used.

When registers are to be installed at dams, provision should be made in the design of the dam for a well of ample size and a shelter to form part of the structure. The same provision should be made when designing bridge piers or bulkheads to be built in streams at points where records may be desired.

Each shelter should be provided with a suitable register table, and a saving of time will result from keeping permanently in each shelter certain tools and equipment. For the small adjusting levers, screw drivers, oil cans, etc., required in operating the automatic register, a small box may be fastened to the wall of the shelter. A couple of thin battens conveniently placed will serve as a paper rack, behind which may be placed stationery or wrapping paper that may be required at the station. A broom will frequently be found useful, and a tin pail, a shovel, an ice chisel, a stay line and lead meter weights should be kept at the shelter when current meter measurements are made nearby.

CARE AND COMPUTATION OF RECORDS

Records from Gurley Printing Water Stage Registers should be wound on a tin spool furnished for that purpose, as soon as they are received at the office. A No. 632 Tape Reel (See Fig. 46, page 90) will be of material assistance in this process, especially in dividing the record for computation, into days, by means of pencil lines drawn across the paper strip. One months record may be rolled on one spool, and the spools may be filed in a filing cabinet or drawer. All information pertaining to the gage height should be made on separate sheets, which are then properly filed away for reference. The printed

*Miller Manufacturing Co., 8000 Alabama Ave., St. Louis, Mo.
**Metal Shelter Co., Whitehall Bldg., New York City.

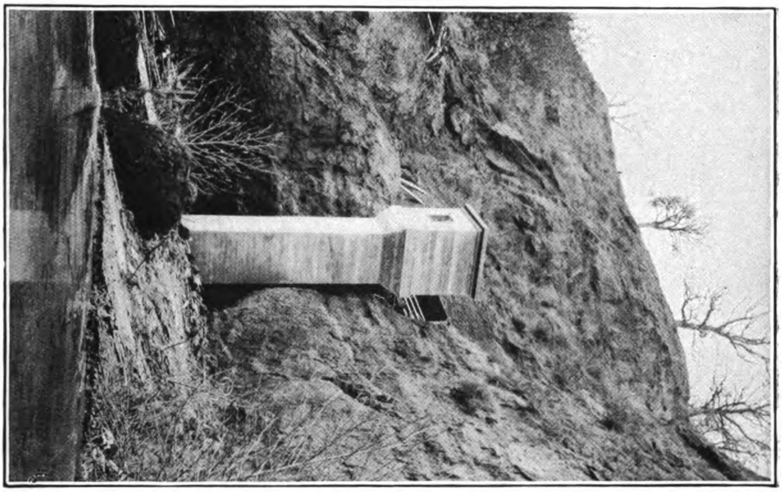

Fig. 60.—Reinforced Concrete Well and Shelter installed by U. S. Geological Survey on the American River at Fairbanks, Cal.

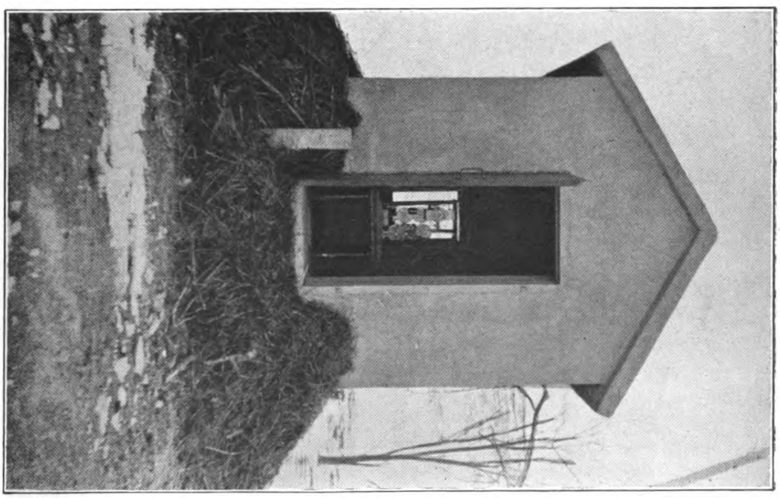

Fig. 61.—Concrete Shelter containing a Gurley Printing Register, as installed by the U. S. Geological Survey on the Genesee River at St. Helena, N. Y.

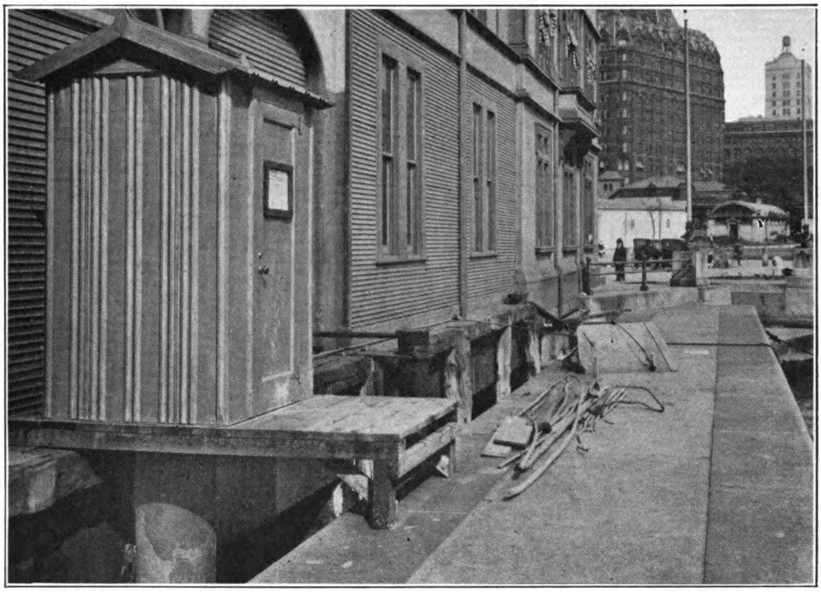

Fig. 62.— Galvanized sheet metal Shelter and Well, installed by U. S. Engineer Department at Pier A, the Battery, New York City. Equipped with a No. 630 Gurley Printing Register—one of 19 similar instruments installed along the Hudson River for a distance of 150 miles between New York City and Troy.

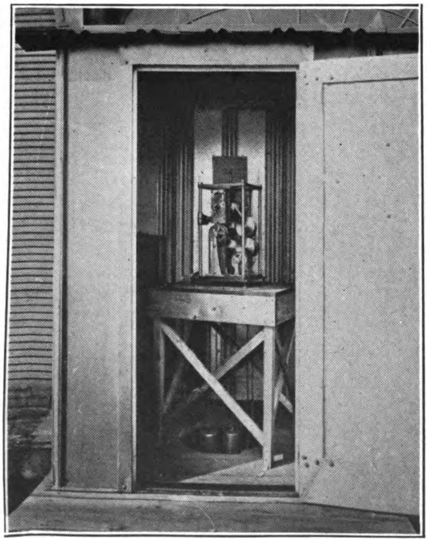

Fig. 63.— Metal Shelter with door open, showing the Gurley Printing Register — with its cover removed — standing on a wooden table ; also the weights suspended in the well.

FIG. 64.—Wooden Well and Shelter housing a No. 636 Gurley Graphic Register installed by the U. S. Geological Survey on the Genesee River at Jones Bridge near Mt. Morris, N. Y. The river is shown under flood conditions during March, 1916, when the Register obtained a complete record of the flood.

FIG. 65.—Water Stage Register installation by U. S. Geological Survey on the Santa Maria Creek in California, showing an inexpensive wooden shelter, a vertical staff gage, and an artificial control.

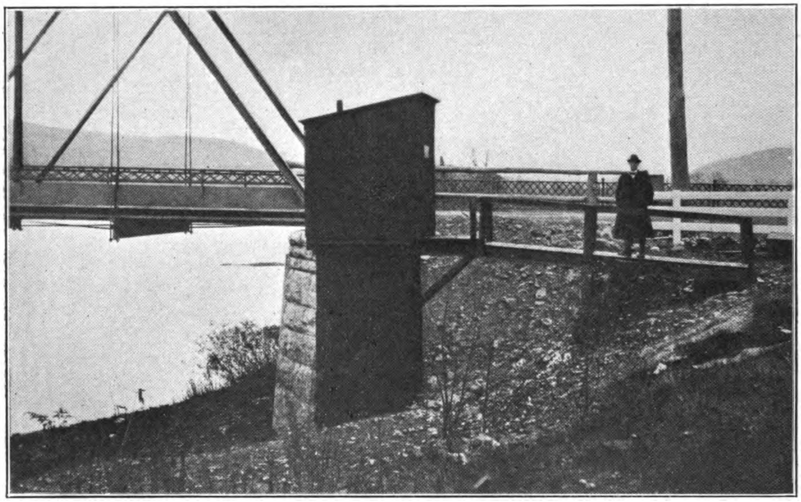

FIG. 66.—Wooden Well and Shelter installed by the U. S. Geological Survey at a bridge abutment on the Susquehanna River near Conklin, N. Y. Note elevation of shelter to provide for flood stage.

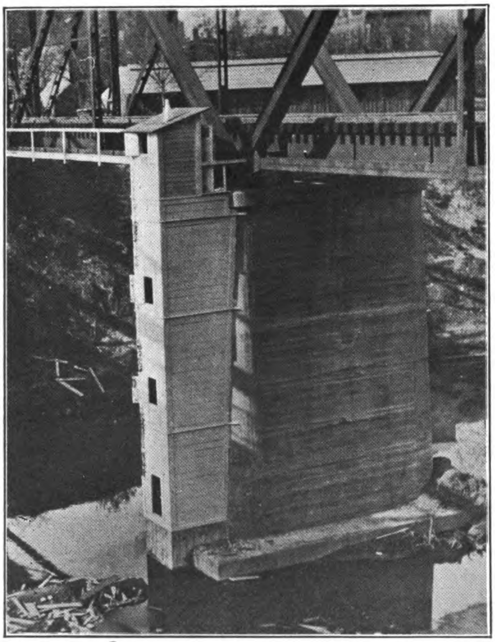

FIG. 67.—Wooden Well and Shelter installed by the U. S. Geological Survey on the Brazos River at Waco, Texas. Equipped with a Gurley Graphic Register. Note method of installation against bridge pier, instead of at usual place on stream bank.

DEPARTMENT OF THE INTERIOR FILE NO.
UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH Washington______
Date____________191___ Field ____________

INSPECTION OF AUTOMATIC GAGE

________________________________ River, at ____________________________

Was gage working properly when you reached it?______________________

What is correct time by your watch?_________________________________

What is the clock time?____

What is the time by the pen or pencil?______________________________

What is the outside or river gage reading?__________________________

What is the inside or well gage reading?____________________________

What is the automatic gage reading?_________________________________

Have you marked pen or pencil time on the chart by raising the float?______

Did you remove old sheet and put on new one?____________At what time did you do this?_______________________________

If you did not remove sheet, did you correct setting of pen or pencil and clock?_________________________________

Did you wind clock?__________________ Regulate it?___________________

Did you sharpen pencil or fill pen?__________________________________

Did you mark pen or pencil time on new sheet by raising float?____________

Have you filled blanks on old sheet according to instructions?____________

Have you made sure that pen or pencil is down, sheet placed correctly, set screw on drum fastened, and gage working correctly before leaving station?____________________________

Have you filled all blanks on this sheet according to instructions?_________

Remarks and questions : ____

____

____

____

____

____

____

Signed by_____________________________________

Observer.

FIG. 68.—U. S. Geological Survey Form for Inspection of Recording Register Stations.

strip should be dated and otherwise marked for identification, and the computations should be made at once. The computer sits down at the adding machine with the record on the tape reel and with a rating table having the gage heights carried out to hundredths; then looks up the gage height for each hour and takes out the corresponding discharge on the machine. At the end of the day the twenty-four discharges are totaled. All these additions are made on letter size paper, one sheet holding the computations for about twelve days, each column of figures being headed with the date. A sheet of carbon paper is reversed behind the paper so that it can be reproduced by blue printing when necessary. By this method, one month's record can be totaled in about two hours.

The pencil records from graphic type registers should be inked in with black drawing ink, using a fine pen. The inking may be done on the back of the sheet, thus preserving the pencil record in its original form, by placing the record on the glass cover of a shallow frame which has an electric lamp underneath.

Notes or other information pertaining to the gage height should be entered on the original sheet, as should also the name of the station, the date of the end of the record, and the gage height scale. In some cases it may be advantageous to use a rubber stamp for this data.

For use with the graphic type registers a discharge scale for each station may be pasted on a celluloid triangle. A steel straight edge may then be clamped on a drawing board over the record in such a position that the triangle sliding along it will always be in the proper position.* The hourly discharges are then read off by the use of the scale and are entered on an appropriate ruled form.

OTHER APPLICATIONS OF GURLEY CURRENT METERS AND WATER STAGE REGISTERS

The successful use of Gurley Current Meters and Water Stage Registers in connection with problems of river discharge has led to their application to similar problems in related fields. Some details of a number of these uses are given below.

*See Engineering News for August, 1914, page 458 ; also for June 25, 1914, page 1430.

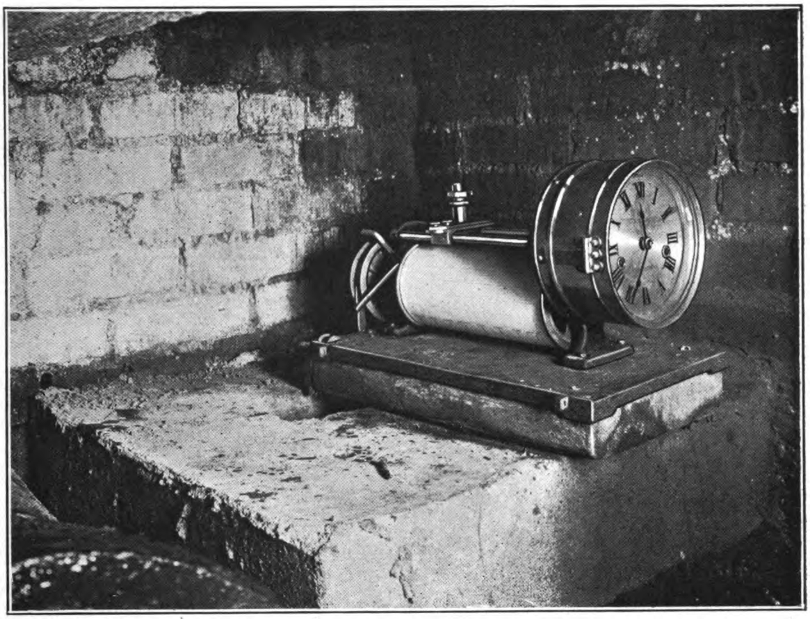

FIG. 69.— One of six No. 634 Gurley Graphic Registers installed in specially designed manholes in the joint outlet sewer constructed by the New Jersey cities and towns of Newark, Summit, South Orange, West Orange, Irvington, Milburn and Vailsburgh. South Orange Township later acquired rights to discharge 500,000 gallons of sewage daily into the sewers of Milburn. It being impracticable to locate weirs in the sewers, owing to the large volume of solids, six Gurley Registers were installed to keep accurate record of the flow. A man visits the instruments once a week to wind the clock and change the charts. The record is kept in natural scale and the total flow is quickly computed.

MEASUREMENT OF SEWAGE

The growth of population of cities and the increased attention that has been given to municipal sanitation has emphasized the importance of the design and construction of sanitary sewers and of works for the disposal of sewage.

As usually designed the sewers are for practical reasons of ample cross-section to afford a wide margin of capacity. With raw sewage being discharged into natural waterways little attention has been paid heretofore to the quantity discharged, and few cities have any record of the actual discharge of their sewers. In many cases the low dilution of the sewage by the natural flow of the stream into which it has been discharged, especially at times of low flow, has been the cause of

many nuisances. Several states have passed laws governing the discharge of sewage into intra-state waters and investigations upon which to base a Federal law, covering interstate streams, are now under way. All such investigations require a knowledge of stream flow. In fact, the question of whether the sewage from a proposed or existing sewer system may be discharged into a given stream may be almost entirely decided upon the basis of the quantity of sewage and the minimum flow of the stream, both of which quantities it is possible to determine completely by the use of Gurley current meters and automatic water stage registers.

The flow of all streams into which sewage is discharged should be a matter of record in every city that disposes of its sewage in this way. Such information may be obtained readily by means of the current meter method of stream gaging, explained on pages 48 to 62.

It is also possible to apply current meter methods to the measurement of the flow in the sewers themselves. In applying these methods, it will be possible to find or to construct in the sewer barrel a permanent control section to be rated. Because of the relatively large diurnal fluctuations of depth over the control to be expected from the character of sewage discharge, it is necessary to use automatic registers. For this purpose Gurley Graphic Register No. 634, with a normal range of one foot, described on pages 110 to 115, is most suitable. The float chamber should be designed as a part of the sewer itself and built at the same time the sewer is. In the case of existing sewers on which it is desired to keep records of flow, a well for the float may be built alongside the sewer at the proper point in its length. Gagings of this character have been carried on successfully in the city of Atlanta, Ga.* and the sewer departments of many other cities are interested in this method of obtaining an accurate record at a reasonable cost of the amount of sewage handled. See Fig. 69.

Weirs have been installed at appropriate places in some systems, with an automatic water stage register to keep a record of the depth of sewage on the crest of the weir. The ob-

*By Mr. Warren E. Hall, M. Am. Soc. C. E., District Engineer, U. S. Geological Survey.

jection is sometimes raised that the introduction of a weir in the line of flow may cause an accumulation of sludge deposits back of the weir. This may be provided for by making an ample outlet to the weir chamber through a quick opening valve by which the contents of that chamber may be rapidly and easily discharged.

In the design of sewage disposal plants the quantity of sewage to be handled by the plant is one of the controlling factors. This factor may be determined by the methods indicated, but it should be noted that the information required is not such as may be obtained overnight, but that its collection will likely extend over a considerable time. Therefore, cities contemplating installations of this kind should be forehanded in the matter of obtaining data.

SOUNDINGS AND TIDE GAGES

When conducting soundings for hydrographic surveys from which to make charts of tidal waters, it is necessary to keep a record of the stage of the tide so that the soundings, which are taken to the surface of the water, may be referred to a permanent datum. Recording water stage registers have been used successfully on such work. They also find a similar use in keeping a record of stage on tidal rivers.

NAVIGATION CANALS

It is frequently desirable to keep a record of the flow of navigation canals. Because of the quantity of water used at the locks, the slope of the water surface varies from time to time, so that a record from a single recording register is not successful. In such cases the method that should be used is that explained in detail by Messrs. Hall, Pierce, and Hall, in Water Supply Paper 345 E, U. S. Geological Survey. In this method the estimates of daily discharge are based on both the gage height and the surface slope between two stations a sufficient distance apart, the hydraulic radius at sections between them being constant. The registers should be located far enough apart to show any appreciable change in slope, and it is absolutely necessary that they be set to the same datum. Automatic recording water stage registers should be used. See Figs. 70, 71 and 72, page 132.

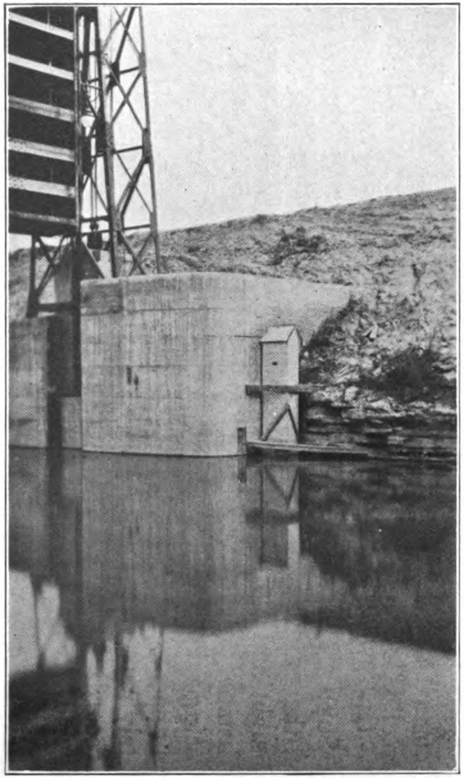

FIG. 70.

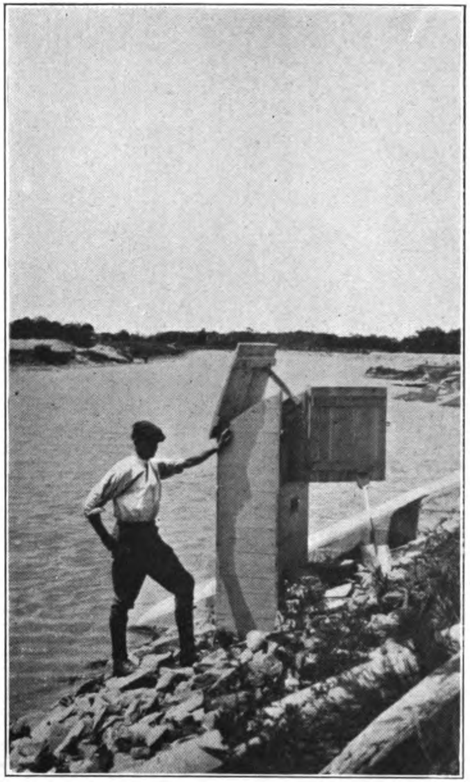

FIG. 71.

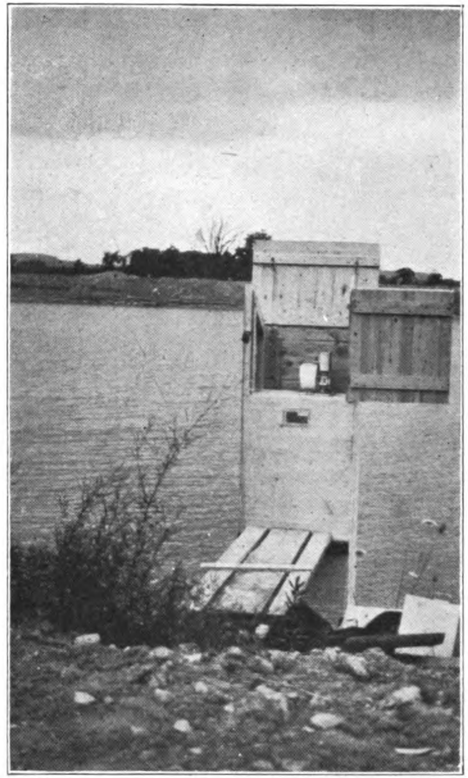

FIG. 72.

Typical installations of a number of Gurley Graphic Registers along the New York State Barge Canal, by the State Engineer's Department, in co-operation with the U. S. Geological Survey.

The temporary wooden shelters are from six to twenty feet high, and measure 18″ x 36″ inside. The small opening underneath the platform is for ventilation, and the top cover raises to permit reading the hook gage.

IRRIGATION CANALS

In all open channels in which a control section may be established at which the relation of gage height and discharge is constant, the current meter may be used with success, the gage heights being recorded by automatic registers. Such methods are applicable to main irrigation canals and main laterals of irrigation systems. The introduction of checks into the subsidiary distributing channels in the course of their ordinary operation causes backwater along their entire length, the slope being very small, and this makes it impossible to use current meter stations which depend on continuous control for their successful operation.

HYDRAULIC POWER STATIONS

The problem of making efficient use of the water available for use in water wheels is constantly before operators of hydraulic power stations. The results of many tests show that operators heretofore have often failed to check up with sufficient care the hydraulic efficiency of their wheels to be sure that they are getting all of the energy possible out of their installation. Frequently, obstructions of various kinds have reduced the flow into the water wheels to such an extent that they are operating at an efficiency far below the manufacturers rating.

It is now customary at well operated power stations to keep careful records by means of which a loss of efficiency in the operation of the plant is quickly detected and localized. Operating efficiency requires that records be kept of the height of water in the forebay, the height in the tailrace, and the height of water flowing over the spillway of the dam. It is possible to keep such records continuously by means of Gurley automatic water stage registers.

FLUMES

Automatic water stage registers may be used to advantage on flumes that have been rated in a proper manner. In such cases the record of stage is made by the water stage register, and this record is applied to a table of discharge.

WEIRS

A similar application of automatic registers is desirable at weirs for measuring flow in cases where the head on the weir varies.

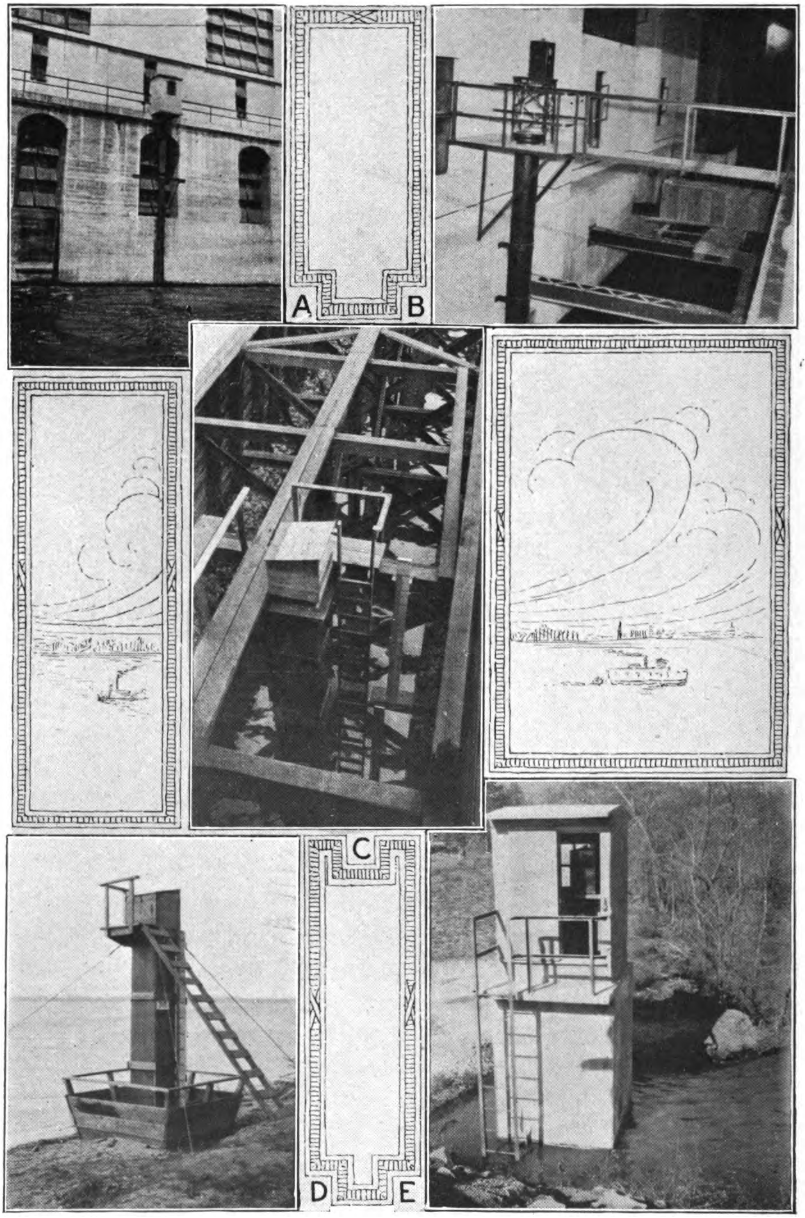

Fig. 73.—Typical Installations of Gurley Printing and Graphic Water Stage Registers by the Stone & Webster Engineering Corporation, for the Mississippi River Power Company, which used seventeen Gurley Registers to obtain accurate records for the efficient operation of its power plant at the Keokuk Dam. Views A and B show two of the four Printing Registers used to obtain elevations in the forebay and tailrace of the power house. Views C, D and E show installations along the Mississippi River at considerable distances above and below the dam at Keokuk.

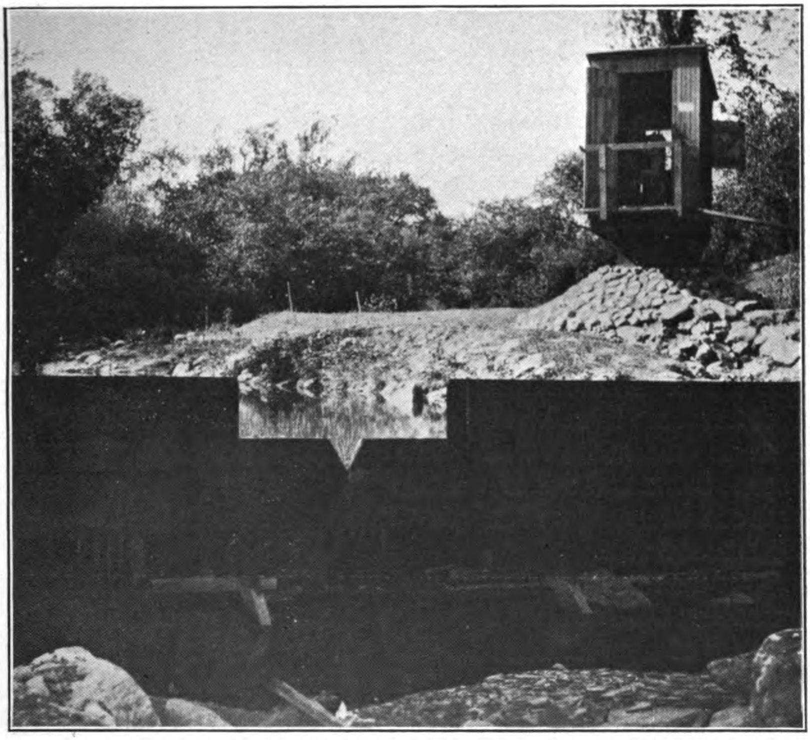

Fig. 74.— Installation of a Gurley Printing Register by the U. S. Geological Survey on Alplaus Creek near Charlton, N. Y., to record the flow over a V-notch weir.

If refined measurements are required the coefficients used in the weir formula by which the discharge is computed should be obtained from an actual rating of the weir used. Weir coefficients that are obtained in the laboratory do not apply accurately to weirs used in the field, unless they are of the same design and are set up in the field and used under the same conditions that existed when they were rated.

The following precautions should be observed when using weirs in the field:

No water should be allowed to leak past the ends of the weir nor under it. In the case of permanent weirs special precautions are taken during construction to guard against such defects. In the case of temporary weirs particular attention

must be paid to this detail. Gunny sacks are frequently used with temporary weirs to prevent leaks. Sand bags and puddles have also been used.

The water should fall freely over the crest of the weir and the distance from the crest to the bottom of the channel in which it is inserted should be greater than three times the head of water on the crest in order not to suppress the contraction. For the same reason, on a weir with end contractions the distance between the edges of the weir and the sides of the channel should be three times the depth of the crest. The depth of water on the crest of a weir is usually much less than the breadth of the crest. The depth should be not less than 0.1 foot nor more than 4.5 feet, in order to keep within the range of tests on the standard weir. The breadth of the crest ordinarily ranges between 0.5 foot and 20 feet. The maximum discharge that can be gaged conveniently on a weir 20 feet long is about 200 second feet.

If the water approaches the crest of the weir with a velocity exceeding 0.5 foot per second, a discharge formula involving velocity of approach should be used.

The automatic water stage register should be placed far enough upstream from the crest of the weir to be beyond the curve taken by the water as it approaches the weir.

A full discussion of the theory of weir measurements will be found in text books on Hydraulics, many of which include tables that facilitate computations of discharge. In Water Supply Paper No. 200, U. S. Geological Survey, will be found a valuable discussion by Mr. R. E. Horton, M. Am. Soc. C. E., of many weir experiments.

SUGGESTIONS FOR THE SELECTION OF AUTOMATIC WATER STAGE REGISTERS

There are two classes of automatic water stage registers. One class makes a continuous printed record of stage and time; the other class makes a graphic record of stage and time.

In selecting an automatic water stage register careful attention should be given to the conditions under which it is required to work, and to the type of record required.

PRINTING REGISTERS

The printing register is especially well adapted

(1) To situations that require a record in type.
(2) To inaccessible locations.
(3) As a convenience in operation at other stations.
(4) Where only non-technical assistance is available to compute the records.

Printed records of stage and time have a single definite meaning and hence are not affected by personal equation when used by different individuals. For this reason printed records are particularly well adapted to those situations in which a legal interpretation of the record is to be made. They are also well adapted to the use of water commissioners, operators, and owners without technical training in the use of graphic records.

When the record is to be made at a location which is not easily accessible and hence at which it is necessary to have a reliable and readily interpreted long time record, *unaffected by weather conditions,* the printing register meets fully all of the requirements. Gurley Printing Registers have operated continuously in many situations of this kind for six months without attention.

At many locations the record sheets must be changed by assistants who are not able to follow a regular schedule. At such places continuity of the record of the printing register is unaffected by such irregularity.

Printing records are easily compiled. It is often convenient to have such work done by power house operators or others not familiar with graphic processes. Printed records lend themselves readily to such uses.

Printing registers record the stage to single hundredths of a foot. The frequency of the record may be varied within certain limits to suit the requirements of particular cases. As ordinarily constructed, Gurley Printing Registers print the record at intervals of fifteen minutes, but it is possible to arrange registers to print every half hour, or every hour.

GRAPHIC REGISTERS

Gurley Graphic Registers give an accurate hydrograph, or curve, showing the relations between stage and time.

One type (No. 633 — see Fig. 50, page 103) makes a reduced size record of stage, while the other (No. 634 — see Fig. 54, page 111) makes a full size natural scale record. The scale of stage should be selected so as to allow the gage height to be read to the required degree of fineness. This is decided in accordance with the precision required in each particular case after considering the percentage effect on discharge of different variations of gage height. The range of stage is usually selected so that ordinary fluctuations of stage are recorded entirely within the range of a single turn of the cylinder. This, however, is merely a matter of convenience, because the cylinder will continue to revolve and extraordinary fluctuations of stage will be properly recorded, the range of stage being unlimited.

The Graphic Register is especially adapted

(1) To general stream gaging work.
(2) To permanent intallation at power plants.
(3) To use in sewage disposal plants.
(4) To use in sanitary sewers.
(5) To use in reservoirs.
(6) As a portable gage in making special studies.

The utility of all stream flow records is based on an accurate, dependable record of gage heights or water stage. Such records are clearly made on properly ruled coordinate paper by Gurley Graphic Water Stage Registers. They are easily installed and are exact and constant in their operation, having been developed to meet actual field conditions, and require a minimum amount of attention. The record is a continuous curve covering seven days time. The record sheet must be changed at least every seven days, but is of sufficient length to allow some variation in the exact time of making the change.

The graphic record shows at a glance the stage and time relations, and is easily interpreted. It is adapted to any graphic method of calculation. The range of stage, which is unlimited, is adjusted to particular needs by the use of proper gear combinations to give an appropriate scale ratio for stage. The time scale is ordinarily one inch per hour, but time screws can be furnished to give a one day, or four day, time scale.

Accurate information in regard to the water stage in both forebay and tailrace at all water power stations is necessary. At such stations Gurley Graphic Registers afford a method of obtaining and recording the required information in convenient form. Provision should be made in designing the power plant and its accessories for the proper installation (See page 134) of water stage registers.

Such records frequently prevent disputes and often assume great importance in legal actions concerning the use of the water.

The successful operation of sewage disposal works requires an accurate knowledge of the quantity of sewage to be treated. Such knowledge may readily be obtained by the use of Gurley Graphic Registers properly installed. The quantity of effluent discharged and its degree of dilution may also be determined by such use. See page 130.

The quantity of sewage flowing in trunk sewers or in intercepting sewers may be readily determined by the use of Gurley Water Stage Registers. This information is essential to and should preceed the design of sewage disposal works.

A record of the height of water in reservoirs, and its fluctuation, is easily obtainable by the use of such registers. This is desirable in all reservoirs of any domestic water supply system. Such records aid in the successful operation of the systems. The head and its fluctuations are very important elements of efficient operation where water is pumped into distributing reservoirs. In such situations records are essential.

Many industrial operations require the storage in tanks or reservoirs of liquid materials, the quantity of which it is desirable to record. Gurley Graphic Registers are well adapted to such requirements. They present in compact form a convenient record of such manufacturing processes.

The accurate determination of gage heights is an important part of many special hydraulic investigations. The graphic type of record is especially valuable in such work, because of the form in which the record is presented. The possibility of varying the scale of the record, which may be accomplished by an alteration of the gear relations on Register No. 633 (See page 101), makes it the most flexible register on the market for such studies.

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